# PRODUCT DEVELOPMENT PROCESS IMPLEMENTATION – EXPLORATORY CASE STUDIES IN CONSTRUCTION AND MANUFACTURING

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## ABSTRACT

The problems of construction are well known (Egan et al., 1998). The increasing complexity of modern buildings, rising pressures for reducing process lead-time and costs, and the growing necessity of fulfilling client requirements lead to an ever-increasing importance of product development processes (PDP). The construction industry has been trying to improve its processes for many years. This led to the development of a number of process models, which are important management tools for understanding how value is delivered to customers (Winch and Carr, 2001) and to suggest improvements. Unfortunately, the implementation of these models in practice is very slow and until now there are no measurable and demonstrable improvements resulting from these process models. Thus, there is a need of a better understanding of the issues involved in implementing product development processes. The aim of this paper is to explore the implementation of process models within construction and manufacturing companies. It presents the results of exploratory case studies, which are part of an ongoing PhD research. The main results describe that there is clarity of the importance and methods used to develop process models, but little information is available either in the literature or within companies on how processes can be implemented. Furthermore, people issues are pointed out as the main barriers to implementation.

## KEY WORDS

New product development, process, implementation.

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## INTRODUCTION

The construction industry has been trying to improve its processes for many years. This led to the development of a number of process models, which are important management tools for understanding how value is delivered to customers (Winch and Carr 2001) and to suggest improvements. The aim of this paper, based on an ongoing PhD research, is to explore the implementation of product development processes within construction and manufacturing companies through exploratory case studies. Three companies were investigated; two from construction and one from the manufacturing domain.

The data from the cases will inform the development of a framework (process and guidelines) to support the definition, implementation and monitoring of product development processes in construction. On this basis, *definition* means the adaptation of generic or high-level processes to specific project processes; *implementation* means the effective use of the high-level process to guide the development of different projects (product development), i.e. using the process to guide actions in the real world; and *monitoring* address the use of measures to observe and propose improvements to the PDP.

In the first section of the paper the benefits from using of the concept of product development in construction are described. It is followed by a discussion on the evolution of research in product development and design, describing when and why research efforts shifted focus to them, and also presenting some research findings on the development of process models. Section four present two different process approaches, the high-level (or lifecycle) approach and the operational approach derived from the operations management research. The need to integrate these approaches is described. Finally, the exploratory case studies are presented and the main results discussed.

## THE CONCEPT OF PRODUCT DEVELOPMENT IN CONSTRUCTION

In manufacturing "***product development process*** is the sequence of steps or activities which an enterprise employs to conceive, design, and commercialise a product" (Ulrich and Eppinger 2000). Thus, PDP comprises the set of activities needed for the conception and design of a product, from the identification of a market opportunity to its delivery to the final client.

The design and construction process can be analysed as a PDP, since it describes the activities needed to develop a product, i.e. a constructed facility. The main benefit from approaching design and construction as a PDP is that it drives to a more integrated view of the process. Also, it makes the transfer of good practices from manufacturing to construction easier. Projects within construction are usually developed by fragmented teams, with poor consideration of client needs, and are generally delivered out of budget/schedule. These issues have been analysed in manufacturing for longer than in construction, thus improvements achieved in the former could be translated to the latter.

In fact, due to the specific characteristics of construction, PDP is slightly different from manufacturing. In manufacturing, design is generally used to produce a number of units of the same product; while in construction, it aims to a unique product. Another difference relates to the existence of manufacturing activities within design, such as prototyping, and making tools and dies. Due to the nature of construction products, it is usually not possible to have prototypes, and physical production tend to be segregated from design.

Nevertheless, when comparing the processes needed to develop a product in construction and manufacturing, a number of similarities become clear. Some examples are: (a) the importance of client requirement capture and translation into product specifications (Kamara, et al. 2000; Cooper 1994); (b) the product is developed by teams with different areas of expertise, thus there is a variety of people with different skills and knowledge involved in the process; (c) the main process stages are similar, see for instance Kagioglou et al. (1998) and Ulrich and Eppinger (2000); (d) there is a great amount of information, information flows and trade-offs within the process (Austin et al. 1999; Reinerstein 1997); (e) there is a strong unpredictability element (Houovila et al. 1997; Reinerstein 1997); (f) it is a highly uncertain process; among others.

Thus, the design and construction process are addressed in this research as the PDP in construction, aiming at achieving a more integrated approach and at simplifying the translation of good managerial practices. Focus is given to the process front-end (design) due to its importance in defining the quality of the product and its impact over production. The next section addresses the evolution of research in product development, describing the main reasons why research has been focusing on PDP improvement.

## EVOLUTION OF RESEARCH IN PRODUCT DEVELOPMENT

### MANUFACTURING PERSPECTIVE

Until the end of the eighties, knowledge on how products are developed and launched was very limited (Cooper 1994). In the nineteen eighties intense international competition has focused increasing attention on fundamental sources of superior performance in manufacturing (Clark et al. 1992).

The search for an understanding of manufacturing performance also led to the offices and laboratories in which decisions about product design are made, and a new model for rapid product development has also emerged; both paradigms are rooted in the same philosophy, that focuses to solve problems rapidly, prevent errors, and continuously improve (Clark et al. 1992). Thus, the importance of the design of a product in terms of its critical impact over manufacturing cost and quality and the fact that it can provide and sustain competitive advantage started to be recognized (Maylor and Grosling 1998).

In fact, the amount of research published on the subject of new product development in the nineteen nineties demonstrates that it has been receiving the level of attention that total quality management (TQM) did during the nineteen eighties (Maylor 1997). More holistic approaches, for example Clark and Fujimoto (1991), which emphasises the importance of the integration of manufacturing and product development management were also developed.

### CONSTRUCTION PERSPECTIVE – EVOLUTION OF RESEARCH IN DESIGN

The search for an understanding of how people perform complex cognitive activities has been the underlying principle of design methods research for the past four decades (Kalay 1999). During this period, there has been a slow but steady growth in understanding design ability, and the first significant growth in the field of design research is dated from the seventies (Cross 1999). It was hoped that understanding "*how designers design*" would lead to the development of methods and tools to help the reliable achievement of high quality results in design (Kalay 1999).

The recognition of the importance of product development in manufacturing, and the appreciation of the necessity of its integration with production has influenced the construction industry as well. Many problems associated with the fragmentation of construction has been driving the introduction of new processes focusing on various ideas and concepts from the manufacturing domain to help integrate the numerous and diverse aspects of construction (Brookes et al. 1999). From these attempts a number of process models have emerged; some of them are briefly presented as follows.

### PROCESS MODELS FOR DESIGN AND CONSTRUCTION

Some of the existing design models from the architectural and engineering design domain include RIBA (1973); Pugh (1986); Pahl and Beitz (1988); Baldwin et al. (1998), Austin et al. (1999). The RIBA plan of work for design team operation is the most widely used model in current UK practice (Austin et al. 1999). This model is predominantly focused to architectural design, not taking into consideration the work that must be developed by other design specialities nor processes that support the design activity.

Pugh's "total design" model covers generically all design processes, including architecture and engineering. Pahl and Beitz (1988) present a model of engineering design, which can be business or industry-specific, but it is still an overview of the process. Baldwin et al. (1998) produced a model for the concept and scheme design stage and Austin (1999) developed a model for the civil and structural engineering elements of the detailed design stage.

Through the development of design models a consensus has emerged, and so far many of them present similar basic features (Maffin 1998). Most models represent the process at a high level, acting as an overview (Austin et al. 1999). They represent design as a group of stages, sub processes, or activities, which occur within an information flow, with different actors performing each activity. Furthermore, generic improvement principles can be derived from these models. However, there has not been a widespread acceptance of these models within the industry. This can be partially attributed to the limited scope of most published models, and the border conditions imposed by the modelling methodology used. The lack of information available in both literature and in the companies on how to implement processes in real settings also contributes to this scenario.

The insight that construction is a process is not new, but a widely and shared process perspective is still needed (Winch and Carr 2001). A research project in which manufacturing experiences and product development good practices are translated to construction is the Process Protocol (Kagioglou et al. 1998); it is described in the next section.

## APPROACHES TO PROCESS MANAGEMENT

### HIGH-LEVEL DESIGN AND CONSTRUCTION PROCESSES

The Process Protocol is a high-level process map devised through the collaborative research of academic institutions, construction organisations and clients. It attempts to integrate all phases involved in bringing a building to a client, examining construction at an overview level. The PP is described as a set of definitions that provide the basics to allow the organisations involved in a construction project to work together seamlessly, offering a common approach to any project (Kagioglou et al. 1998). The key principles presented are: whole project view; progressive design fixity; a consistent process; stakeholder involvement/teamwork; coordination; and feedback.

The importance and need for high-level processes has been largely described in the literature (for instance, Egan 1998). A high-level process presents the strategic approach necessary to ensure that all stakeholders understand the process in a similar form, describing the overall process principles. These principles can be either based on research findings or in what is considered important within a specific business environment.

Furthermore, high-level lifecycle models are necessary due to the fact that specific project processes are not translatable between different projects because of the variability and uncertainty associated with them, e.g. different contractual arrangements imposing different process strategies. Besides, these models can help overcoming the project challenges, i.e. delivering as scheduled, budgeted and with customised value.

To allow the implementation of generic processes, a detailed level of analysis must be done within each project, through which the activities and their relationships will be defined. The implementation of process models is a research area that appears not to be sufficiently developed. The steps necessary to adapt a high-level project process model into specific project processes are yet to be established.

## OPERATIONS MANAGEMENT APPROACH TO DESIGN PROCESS IMPROVEMENT

From the operations management point of view, processes are analysed through a more detailed approach, considering what happens throughout the development of work, i.e. processes are analysed as being composed by transformations, flows and value generation, as described in the TVF theory (Koskela 2000).

Through operations management a number of process issues can be understood, analysed and therefore improved, for instance the need to reduce process variability, or value loss (see table 1). These issues are too specific to be addressed through high-level processes, and they need to be analysed while the process develops. Also, it is necessary that the PDP enclose certain degree of stability to allow the analysis of the transformation, flow and value aspects. This means that projects should be developed through similar processes to allow the detail analysis and continuous improvement proposed on the operations management research to occur. Process stabilisation can be achieved within companies through the implementation of high-level process models.

The main design problems related to transformation, flow and value generation, and the potential solutions according to the operations management research are summarily described in table 1. It also presents some of the barriers to the solutions presented, based on the literature and also on the empirical research.

## DISCUSSION - INTEGRATION THROUGH A GENERIC IMPLEMENTATION FRAMEWORK

An assumption of this research is that the two different levels of process analysis described above are appropriate and necessary. Furthermore, these approaches can only be integrated through process implementation.

It is difficult to use detailed models to guide work execution because of the variability and uncertainty involved in projects. Thus, it appears that the definition of a high-level process and its use in different projects, with the aid of an implementation framework, is an alternative approach. This will enable an iterative process, where the analysis of the process model (as a description of what ought to happen) together with the complexities of the real world will allow people to act upon the world and improve it.

*Table1: Main problems related to transformation, flow and value generation in design, potential solutions from literature and possible barriers to solutions*

| | PROBLEMS | POTENTIAL SOLUTIONS | BARRIERS TO SOLUTIONS |
|---|---|---|---|
| **Transformation** | • Decomposition is not sufficient to understand / improve design[1] | • Framework of concurrent engineering (CE) [1;2] | • Slow implementations of CE[5]<br>• Difficult to predefine act. & inf. flows |
| | • Non value adding activities are not explicitly represented[1,2]<br>• Long duration and not enough time to generate solutions | • Explicitly representing and avoiding non value adding act.<br>• Process transparency, leading to less waiting times and insp. | • Variability; difficult to predict non-value adding act.; tools are complex & time consuming, thus not widely used in practice* |
| | • Partial design, from the point of view of one discipline only [1] | • Improvement of collaboration<br>• Process visibility<br>• Consensual definition of process | • Contractual relationships in place;<br>• Lack of consideration of stakeholders inf. needs |
| **Flows of information** | • Changes in requirements | • Clear identification of client requirements | • Large number of req.; conflicting req.; poor briefing[3]; difficult to explicit req. |
| | | • Clear definition of project scope | • Business and project strategy are not always clear; changing business needs |
| | • Effort to transfer information | • Teamwork, empowerment of the team, informal communic.<br>• Re-arranging tasks (inf. flows) | • Difficult to establish the flows of information far in advance of the design |
| | • Time consuming or insufficient interactions to improve design [2] | • Reduce interactions through DSM; consider all life cycle | • Difficult to implement DSM;<br>• Lack of whole process view |
| | • Uncertainty due to lack of definite information [1,4] | • Prototyping/simulation tools | • Refusal to commit finances[3]<br>• IT cost/benefit not clear |
| | • Uncertainty due to lack of decision | • Freezing design decisions | • poor req. mgt & consideration of stakeholders needs; Failure to maintain proper records of projects [3] |
| | • Rework caused by design errors detected in latter phases [2] | • Mgt of internal client needs<br>• Control inf. flows & changes<br>• Improved communications[1] | • Large number of inf. & changes in the inf. makes control difficult<br>• Control seen as a barrier to creativity |
| | • Transfer of information | • Team approach; Collocation empowerment of the team | • Current procurement methods and contractual relationships; cultural issues |
| | • Waiting of information- high level of capacity utilisation [4] or waiting for customer decisions | • Concurrency; splitting design tasks & informal communications | • Variability in business needs (design offices and client organisations) |
| | • Unnecessary work | • Definition of work to be done<br>• Inf. flows monitoring to avoid rework due to assumptions | • Lack of process visibility & late involvement of designers; Lack of consensus leading to work overlapping |
| | • non compatibility of IT tools causing waste | • integration of the systems used in practice | • long term effort to create industry standards |

[1] Koskela 2000; [2] Huovila et al. 1997; [3] Barrett & Stanley 1999; [4]Reinerstein 1997 [5]Brookes et al. 1999

| | | | |
|---|---|---|---|
| **Value generation** | • Design is not conceptually related to its costumers | • Req. mgt and client involvement within design<br>• Better integration of costumer decision-making in design [1, 3] | • Existing req. mgt models are not integrated with the process;<br>• Process goals do not precede the action but emerge from it [3] |
| | • Not all needs are identified in the beginning of the process | • Req. mgt and client involvement within design | • Req. evolve while design develops, thus need considerations throughout the process |
| | • Missing or evolving requirements | • Rigorous requirement analysis<br>• Better mgt of client req<br>• Co-operation with costumer | • Lack of a effective methodology to manage requirements<br>• Client not willing to get involved |
| | • Loss of requirements | • Formal links between req. & solutions (QFD) | • QFD is not used–cost and time issues |
| | • Optimisation | • Teamwork; Collaboration; Commonly held goals; Mutual consideration of decisions<br>• Complete visibility | • Lack of an agreed process in use<br>• Designers are trained to be independent individuals who create unique products thus collaboration is difficult |

* DFD's & IDEF0's = complex due to the amount of information analysed; DSM depend on the predefinition of inf. flows far in advance of the design activity, thus is not effective due to high variability

** act = activities; inf. = information(s); insp.= inspections; req= requirements

Implementation can include process development and use, or it can be approached as the use (action) of an existing process. This research includes two different aspects, the adaptation of the high-level model into a specific project process and its use in real settings (as presented in figure 1) i.e. the use of the specific process to manage and monitor the PDP, allowing the analysis of the transformation, flow and value generation, based on the status of development of the project.

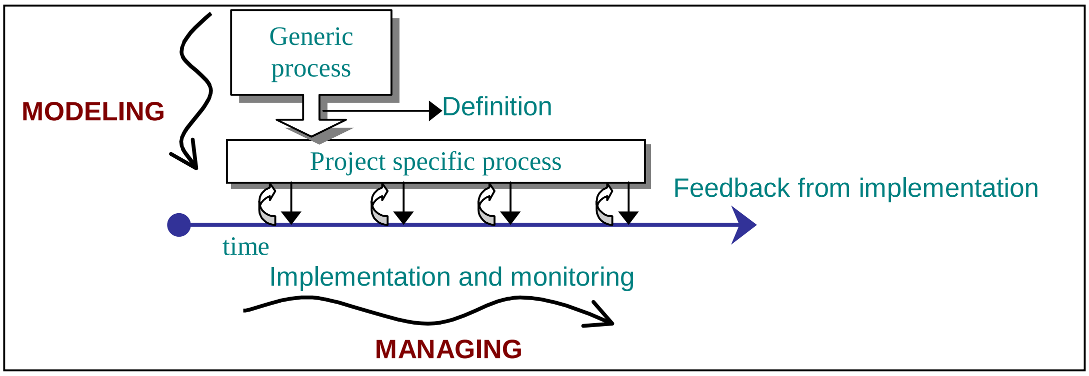


*Figure 1: issues to be considered in the implementation model*

## EXPLORATORY CASE STUDIES

### OVERVIEW

This paper presents the main results of exploratory case studies, which have had both exploratory and explanatory characteristics. They consisted of a set of semi-structured interviews as well as documentary analysis. The purpose was to identify: (a) innovative/ good managerial practices in PDP implementation in manufacturing and construction; (b) how generic project processes are defined, implemented and monitored; and (c) factors that inhibit and enable the implementation of generic project processes.

Two construction companies and one manufacturing (telecommunications) company were involved in the study. Company A was selected because it is a major company with recognised good practices in the PDP. Company B have developed a high-level process for product development, based on good practices identified in academic initiatives and also on manufacturing (based on company's C process). Finally, company C (manufacturing) was selected due to the fact that it has a well-established high-level process, which has been used to manage their new product development for more than ten years. Thus, good process implementation practices could be identified.

### COMPANIES CHARACTERISATION

Company A is a major construction company with operations in the UK, North America, France and Asia. It employs 50,000 people in more than 40 countries. The interviewee is the business services manager of the nuclear business stream. It does not have a generic process for design and construction. Conversely, it has improvement initiatives focusing on specific (sub)processes. One interview of two hours was conducted in this company.

Company B is a defence and aerospace company developing naval platforms, military aircraft, etc. The interview was conduced within the construction division of the company, which is responsible for all new buildings, refurbishment and demolition, having in average sixty major projects a year. Company B have finished developing a high-level process for the design and construction process. A two-hour interview was conducted with two persons responsible for the development and testing of the model.

Company C is a major global provider of communications and IT solutions. It employs over 48,000 people in 100 countries including Europe, North America, Africa, Asia, and Australia. Their main products are: broadband switching infrastructure (applications for networks); access and transmission products; and optical networks. Two interviews of two hours each were conducted with the vice president of performance management and the projects development manager.

## MAIN FINDINGS

### COMPANY A

Company A has been using processes to manage the work between projects and to allow the understanding of best practice. Even though it does not have a high-level PDP in use, the need of having processes is recognised. Accordingly, the high-level process would allow the knowledge transfer and learning between different projects.

The interviewee described two major improvement initiatives focused to the nuclear business stream. The first was the development and use of a Brownfield project's process, developed in partnership with a manufacturing company. The aim was that the process would deliver the organisation, pulling designers and subcontractors together. The second was the development of a materials purchasing process. The main findings are described:

#### Definition of what a high-level process is

It was possible to identify a lack of clarity on the concept of what a "high-level process" is, because in one hand it was described as being the project stages, and on the other hand the interviewee stated that the company do not have a high-level process.

### Process mapping and importance of having processes defined

In each improvement initiative different steps to define a process where used; i.e. the steps to define the materials purchasing process were different from the steps used to define the Brownfield projects process. However, in both cases they included similar elements: (a) identification of the problem; (b) establishment of an improvement team; (c) design of the as-is process; (d) new process devise and agreement; and (e) definition of procedures and working instructions. Thus, it can be argued that process mapping and the importance and benefits of having processes defined are well understood.

### What implementation means for the company and main inhibitors

The company addresses implementation as the use of the model devised throughout time, as described in figure 1. However, it was not possible to identify how these processes were adapted to suit specific project processes. This could be for the reason that this adaptation process does not happen in the company, or because this knowledge is not easily available. Thus, it is not clear how the process is used to guide action in the real world. Implementation is thus addressed in a similar way of what is proposed in this research, lacking the adaptation of generic process into project specific processes. The company does not to have any registered information on process implementation.

The main implementation inhibitors described related to aligning the company culture with the client (ad co-developer) culture, and getting the client to buy in to process change, even though they have senior management support in both companies for that. Other barriers described were: (a) the generic process being too detailed and bureaucratic; (b) process variability; (c) restriction related to the kind of project (nuclear); (d) resistance to change and (e) perception of loss of bargaining power.

## COMPANY B

Process management is well embodied within the company B culture, excluding its construction division. This is why a process model was recently devised for construction as well. Company B can be classified as a client with involvement in the process, since they define the problem, budget, and subcontract design and construction of the facilities.

### Process mapping

The process model was devised through iterative steps, described in figure 2.

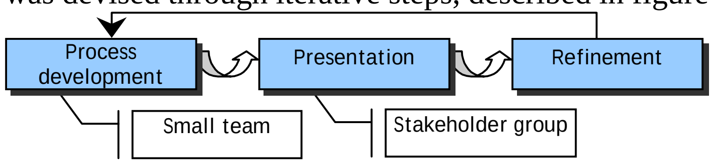


*Figure2: Steps to define a high-level process used in company B*

The high-level process focuses in issues such as project planning, verifying business needs, determining requirements, and project budget. A great emphasis is placed to phase reviews, which involve evaluations/approvals done by independent boards. The process focuses on the activities that must be done within the company as a client, and design and construction activities are not defined. Partnering arrangements initiated the need for establishing and using a high-level process, thus contractual relationships have an impact on process implementation. The model validation started through six pilot projects, which by the time of the interview were initiating. After that, the process will be mandated to all the company's construction work, and it will be published and updated in the intranet.

### What implementation means for the company and main inhibitors

Implementation is addressed as the effective use of the model in real settings. As in company A, process modelling is well understood, but the way that the generic process will be adapted to specific project processes was not defined. Links between the generic process and specific project processes would have to be identified through the analysis of the model use in practice, but this was not possible because this information is considered confidential in the company. Furthermore, the need for feedback and process monitoring is explicitly addressed, but how this will occur is not defined.

Concerning implementation inhibitors, it was stated that it is very difficult to convince people that the process works and describes best practice. Another barrier is that partner companies have got different project processes in use, and they will have to adjust its processes to the client's process. Other inhibitors are: (a) the generic process being too detailed and bureaucratic; (b) business changes and process variability; (c) keeping business expectations balanced and justifying the use of the model if it do not directly lead to cost reductions; (d) resistance to change e.g. people do not use models they don't develop themselves and (e) cultural changes and difficulties in achieving teamwork.

## COMPANY C

Company C's high-level project process is the *lifecycle management*. The process is described as a framework, presenting guidelines and guiding principles that remain the same for all projects. Also, it is considered to be a *vision* for product development, thus it is flexible and people can fit their needs accordingly to the type of project. The process is represented through a matrix, describing nine stages (figure 3) in the horizontal axis and in its left hand side it is divided into management functions. It also has examples on how to make the process flexible, adapting it to different projects, for example merging different phases and determining specific deliverables. The model is based on phase reviews developed by independent chairman.

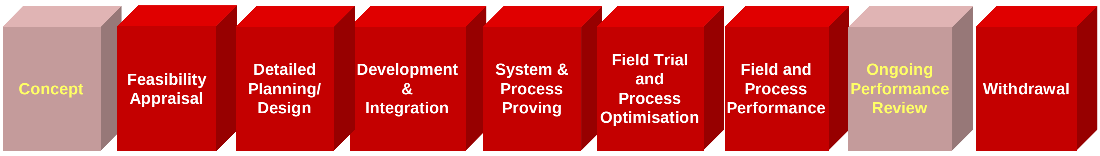


*Figure3: Process models stages in company C*

### Process mapping and levels of abstraction

When the model was first developed, it was believed that it would describe the way all products are developed in the company. Throughout time, the company has had business changes, and the approach to use the process also changed. It was realised that there are differences in the business units, and the organisation believes now that there must be local variations of the high level model. Different processes are defined for each business area, in different levels of abstraction, i.e. generic process for the area, operational level and a detailed process for each project (see figure 4). This is a way of assuring that each part of the business understands and follows the process principles. Furthermore, it allows people to commit and own the high-level process.

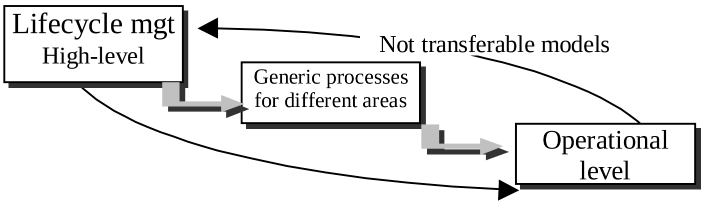


*Figure 4: Different process model layers, or levels of abstraction*

**What implementation means for the company and main inhibitors**

Three main implementation issues were identified: (a) the necessity to create a framework, i.e. the high level process; (b) the necessity of creating the right environment, i.e. the way the company conduct its business must be well defined and senior management needs to support it; (c) the necessity to have leadership from the project manager for the effective process use. Other issues described are:

- the high-level process must not be mandatory otherwise it wont be used;
- the high-level process cannot be too detailed in order not to became bureaucratic;
- implementation requires engagement from all stakeholders;
- language can become an inhibitor of process adoption, and the high-level process can be understood differently by the stakeholders because it is generic;
- Task definition is crucial and it must be done locally;
- The way the process is published is essential for its effective use.

The steps used for implementing processes were identified through the interviews and through a presentation given by one of the interviewees in a research workshop (figure 5).

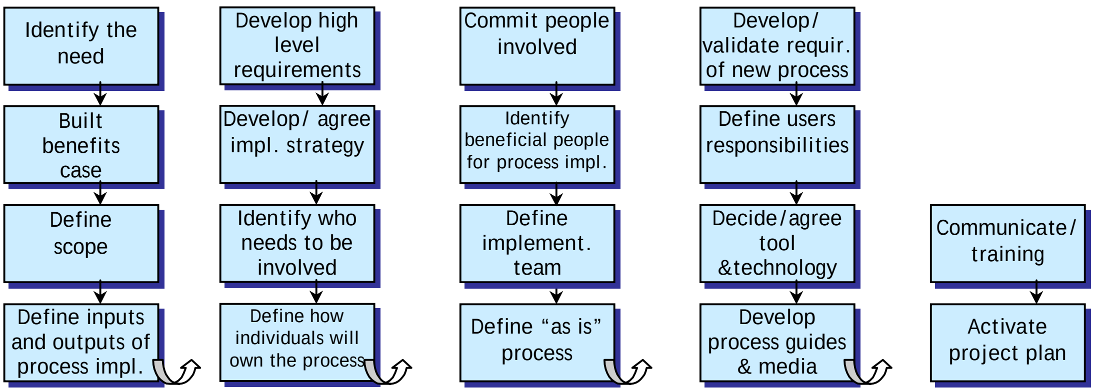


*Figure 5: Steps for implementing processes in company C*

In company C implementation is addressed as the use of the high-level model, considering the adaptation needed from the generic to the specific process as well. That's why there is an implementation process defined. Due to the company size and diversity of activities, this adaptation process is addressed in two levels, i.e. the high-level process to processes for each business area, and then from each business area to the specific project process. Process monitoring and feedback are addressed, but since the processes of each area are not translatable it is difficult to consider good and bad practices throughout different business areas. Furthermore, the importance of having high-level process models is so well embodied into the company that a new process integrating business and the project process is under development.

## 7. CONCLUSIONS

The construction companies possess knowledge on the importance and benefits of having high-level processes, even though there might be a lack of clarity of the concept of high-level processes. Even though, the construction companies interviewed do not have knowledge on how to implement processes or information registered on process implementation. The manufacturing company has recognised the need for an implementation framework and has developed it. The approach used to process implementation is broader than the one from the construction companies, considering the necessity of adapting the high-level model, addressing issues such as process flexibility and the importance of ownership of the people who will use it. This implementation framework might not be appropriate to construction, but it is needed, and this data can be a starting point for construction.

A number of process implementation barriers were identified, relating to the process model adopted, the project context, the implementation strategy, people issues and communication and IT. Differences in companies' culture, resistance to change, and difficulties in transferring learning within and across projects were some of the issues described. Thus, organisational change involving managerial thinking and company's practices must be addressed to allow PDP implementation and improvement.

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