Business and Technical Support for the Design of Agile Production Plants

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Abstract
Many manufacturing companies in the pharmaceutical, agrochemical and specialty chemical industries are pursuing business strategies based on the innovation of high-value products. Such a focus renders agility a key organisational attribute, although past evidence indicates that technical and business aspects need to be more adequately combined to deliver high performance when innovating. This paper describes the results of an action research initiative, involving business school academics, chemical engineers and practitioners, that was undertaken to develop a framework and tools for designing and developing agile processes and plant for these industries. A key aspect of this work has been the integration of business and technical agendas within the framework and tools that were developed and trialed in three major industry case studies.

Keywords: Agile plant, business evaluation, technical evaluation

1. Introduction
Many companies located in developed economies are following business strategies based on innovation of high-value products while ceding manufacture of commodities to those in emerging economies (Porter and Ketels, 2003). Chapman and Edmond (2000), Burgess et al. (2002), and Walsh and Lodorfo (2002) have found this to be the case with many manufacturing companies in the pharmaceutical, agrochemical and specialty chemical industries. Goldman et al. (1995) reported that such a focus on innovation renders agility a key organisational attribute, both for time to market and manufacturing plant operation; however, past evidence indicates that technical and business aspects need to be adequately blended to deliver high performance when innovating (Daft, 1978). The need for an agile production plant is set by the company’s need to speedily introduce new products, and therefore new processes, into the plant. Clearly the business routines for introducing a new product, and new process, are powerful determinants of whether an organisation achieves agility, just as the technical capabilities are. This paper describes the results of research carried out over a number of years to develop a framework for agile plant design that integrates business and technical aspects and provides tools to support the design process. The research

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outcomes described here arise from a collaborative (action research) process involving academics and industry practitioners.

2. Methodology

The research described is based on, but also extends, a major three year research programme funded by industry and the UK Engineering and Physical Science Research Council (EPSRC). The programme aimed to significantly improve agile process and plant design in the speciality chemicals industry through research activities involving four research groups based in three UK universities. In particular, the aim was to provide methods which: halve the total project time from the start of process development to manufacture; lead to significant reductions in total manufacturing time; lead to 30 to 40% reductions in the capital cost of new investments compared to conventional plant; and lead to plant which is inherently more versatile. This paper presents the work of two of these research groups, both based at the University of Leeds, that covered (a) business and technical integration aspects of the research project and (b) agile plant design. The aim of this particular part of the project was to promote a radical change in approach to chemical process development, linked to the design of readily reconfigurable plant and an integrative business model which facilitates assessment of technical and financial options.

The research started with an initial phase consisting of literature search, interviews, questionnaire surveys and process mapping exercises that acted to clarify research objectives and the study scope. The main research phase was undertaken using an approach that can be best characterised as action research (Park, 1999; Stringer, 1999). The first step was for academics and practitioners to conceptualise the problem area – some main features of the area were identified as:

- disconnected business and technical criteria in the new product/process activity (Olson et al., 2001)
- inadequate knowledge of the chemical processes (Charpentier and Trambouze, 1998)
- over reliance on batch production methods and equipment that had been used in the past (Stephanopoulos et al., 1999)

This conceptualisation led on to the design of frameworks and tools to support decision-making within the new process and plant design activities. A limited number of major industry-based case studies were then undertaken sequentially to test and refine the conceptual approaches in an iterative manner.

3. Research Results

In the research it was assumed that new products and processes are designed, developed and introduced on a project basis; as they typically are. Because many organisations rely on a stage gate model (Stevens et al., 1999) to manage projects, such a model - the Business Gate Framework (BGF) - was designed to meet the needs of the companies collaborating in the research (see Shaw et al., 2001). The BGF therefore provided the collaborators with a high level context for their project management.
Within this framework, the first step in dealing with the company’s potential projects is to evaluate the competing business opportunities and prioritise them such that attention is focused on the most beneficial areas. This is done through the Project Impact Priority Evaluation Tool.

A project that becomes the centre of attention is specified in a brief, but essential, document (Project Aims and Description) that captures both the business and technical characteristics.

An exercise is then conducted where business and technical personnel document the costs, benefits and risks related to the project in a Tool for Opportunity Focus, Improvement and Evaluation (TOFIE). This tool captures the key driving forces that then inform the succeeding design and evaluation activities.

Borissova et al. (2003a) outlined how the main technical activities of process and plant design are carried out in a high level process where alternative options, i.e. different outline designs, are generated. Different categories of project options can be identified in relation to the constraints set by existing plant, e.g. situations where minor modifications are projected for existing plant, or a new plant configuration is required but existing infrastructure is to be used, or both new plant and infrastructure are required. The design of plants for families of products or processes based on reconfigurable and interchangeable modules is one approach to achieving the agility required by the business. A network model proposed by Borissova et al. (2003b), used in conjunction with information models, can then be used to explore the plant design options at an early stage. The information models are used to support the information content of the process definition which captures the plant requirements from a process point of view, and to support the definition of a logical plant structure.

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| Figure 1. Overall view of elements in business evaluation of options. |
The primary process tasks are defined in terms of the physico-chemical and chemical engineering parameters such as reaction kinetics, thermo-chemical data, transport properties as well as flow rates or batch quantities. This leads to the requirements for heat transfer, control, etc.

The individual process tasks are then captured in the network model so that the required functionality can be compared with that currently available. This allows the most appropriate choice to be made in the light of the business requirements and constraints.

Plant reconfigurability can be at the level of modules or of equipment – in either case some standardisation of connections (type, sizes and positions in space) for process streams, utilities and control is required. The "plug and play" concept can then be adopted. One proposal is that of a spine containing all the utilities and modules which can be connected to that spine. A change in process can involve either a change of equipment within a module or the exchange of a complete module. Either way, standardisation is one of the requirements for speed of reconfiguration of the plant.

Generated technical options are then evaluated using a business-related framework based on a balanced scorecard approach, i.e. the evaluation philosophy is not dominated by purely financial considerations. Values are estimated and compared for key business performance metrics that operationalise multi-dimensional configurations of finance, speed, quality, flexibility and risk (see Figure 1) - a set of dimensions developed from typical ones encountered in the literature, e.g. Slack et al. (2001). For the project option to be evaluated, metrics are first selected to represent each of the five dimensions. Values for each of the metrics are established from data and parameters manipulated within the analysis tools. The estimated values for the dimensions are then presented in an integrated manner using alternative schemes. As an illustration, a polar plot is shown in Figure 2. A more involved analysis could utilise a multi-criteria decision approach where the sensitivity of the evaluation outcome to different weightings of variables can be explored using software (VISA, 2003). Similarly, the analysis could be based on
stochastic variables using, for example, the @RISK™ (@Risk, 2003) extension to the Excel™ (Excel, 2003) spreadsheet.

The outcome of the evaluation is a selected option that can then be further specified in sufficient depth to go forward to the detailed processes of design, development and construction.

The tools described above were implemented in computer programs to assist rapid option evaluation, and applied successfully in three major industry case studies. The specific details of these studies must remain confidential to the companies and academic partners involved. In general terms, however, the innovative options identified using the framework and tools developed held out substantial benefits. In the first study, which focussed on the modernisation of processing methods that were felt to be dated, the potential for significant reductions in operating costs was identified, with over 8% reduction in materials plus labour costs if a new plant were to be constructed. Payback was also estimated to be within 12 months, with an increase of 30% in operating profits projected for the new plant. The second study, which addressed the production of a fine chemical intermediate from raw material, identified the potential for significant cost savings on the existing process with respect to waste treatment costs and improvements in yield. A new plant option was assessed to reduce operating costs by 64%, and to significantly improve both yield quality and processing speed. In the final study, which concerned the design of a new, purpose-built agile plant, a 40% increase in net income per year, with payback achieved in just over a year, was projected. These case studies demonstrated that the original objectives of the action research initiative were fully achieved, i.e. that the methods developed could halve the total project time from the start of process development to manufacture, and lead to significant reductions in the total manufacturing time and to 30 to 40% reductions in the capital cost of new investments. The final objective, to provide methods that lead to plant that is inherently more versatile, was also considered to have been achieved.

4. Conclusions

The novelty in this research stems from integrating business and technical aspects in a framework and tools that support the design of agile plant. The research outcomes arose from an action research collaboration of a novel nature in drawing on academics from business school and chemical engineering backgrounds. However, the collaboration of academics and practitioners also ensures as far as possible the utility of the outcome for the latter group. The ongoing nature of the research described here means that potential exists for additional work to further refine and develop the approach. One particular area for further scrutiny is obtaining stronger validation of the method from extended implementation of the approach by industry.

Acknowledgements

This work was supported, in part, by a consortium of industrial partners, and in part by the EPSRC, Grant Reference GR/L65949/01.
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