1. Introduction

The Center for Industrial Production (CIP) (see http://www.cip.auc.dk) at Aalborg University in Denmark is an innovative university-industry research initiative aimed at establishing “action research” programs in Danish companies. The CIP seeks to strike a balance between holistic application programs with an industrial focus and theory based development programs. Holistic application programs deal with product development in networks, supply chain management, and strategic manufacturing development, for example. This industrial focus is balanced with theory-based development programs dealing with holistic production concepts, the extended enterprise, intelligent manufacturing, and human resources in manufacturing. Reality-based research is paramount in the CIP and the Center has enjoyed strong industrial support. Some of the partner companies include Bang & Olufsen A/S, LEGO System A/S, Christian Hansen A/S, Danfoss A/S, Grundfos A/S, Martin Group A/S, among others.

One of the central CIP research themes is “Strategic Manufacturing Development”. This CIP application program includes action research that explores the dynamic and complex interconnections among strategy, organizational learning, organizational structure, technology, people, and processes. The focus of this application program is on developing and evaluating pragmatic methods and frameworks for facilitating dialog-based manufacturing strategy development by use of generic manufacturing concepts. Strategy development in organizations is a research topic that has received significant attention in recent years. The importance of using creativity to establish a shared “vision” for manufacturing companies has emerged as a key ingredient to a successful, collaborative process (see Riis and Johansen1; Maslen and Platts3).

Riis and Johansen1, for example, develop a five-phase strategic manufacturing development process that includes the following:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Initiation</td>
<td>Staging and organizing the process, plus clarifying the starting point and the ambition and scope of the process.</td>
</tr>
<tr>
<td>2. External trends and strategic challenges</td>
<td>Creating an organizational shared picture as regards the need for change, external trends and the strategic challenges of the enterprise.</td>
</tr>
<tr>
<td>3. Development of a manufacturing vision</td>
<td>A collaborative dialog-based process designed to capture managers and employees’ innovative ideas and knowledge.</td>
</tr>
</tbody>
</table>

Table 1. A Five-Phase Process for Strategic Manufacturing Development
(Source: Riis and Johansen1)
4. Evaluation of the manufacturing vision
   Evaluation of ideas and elements of a manufacturing vision with respect to strategic challenges defined, and an examination of the risks and resources associated with implementing the developed manufacturing vision.

5. Application and planning of the next steps
   Planning how to proceed by making use of the organizational momentum created, the potential strategic contribution of the manufacturing vision and critical areas for designing a production system.

Riis and Johansen\(^1\) elaborate that strategy development is typically executed in a spiraling process that includes both sequential and iterative elements, as illustrated in Figure 2.

![Figure 2. A Spiraling Process for Strategic Manufacturing Development](image_url)

**Figure 2. A Spiraling Process for Strategic Manufacturing Development**
(Source: Riis and Johansen\(^1\))

However, there is a persistent need for establishing dialog-based process methods that foster creativity and that are easily transferable and adaptable for varied industrial contexts.

As noted, within the CIP, one of the essential application programs for action research is Strategic Manufacturing Development. To enable the achievement of this action research, it was envisaged to develop a laboratory to support strategy development with representatives from various Danish industries. Previously, Riis et al.\(^3\) outlined a model for an Experimental
Production System Design Laboratory that encouraged the integration of different manufacturing perspectives and viewpoints. Central to the laboratory design was the creation of a Model Bank that was intended to be a knowledge repository of production theories and models, methods and tools, case examples, and practical experience. This framework was an important precursor to the Experimental Laboratory for Production (ELP). Since 1996, researchers at Aalborg University through multiple case studies with Danish companies in the P+5 project have demonstrated that it is possible to develop a manufacturing vision in practice (see Riis and Johansen\(^1\)). During these series of industrial cases, individual laboratory elements, such as visualization, plenary seminars, cross-functional cooperation, etc. have been used and evaluated. While any one element by itself is not especially unique, what would be original is the combination of elements into a coherent system. This synergistic approach towards strategic development and research forms the essence of the ELP. Thus, the ELP is but one aspect of the CIP and is intended to enable the development of both content and process tools to facilitate the achievement of the CIP application program of Strategic Manufacturing Development.

2. Organization of the ELP

Physically, the ELP will consist of three connected rooms at Aalborg University. The first room will serve as a plenary capable of hosting 24 industrial participants. Depending on the company specifics and situation, a facilitator will engage these participants in a one or two day strategy development “seminar”; however, the general idea of the ELP is to serve as a break from a traditional seminar environment and to spark “creativity” and “playfulness” among participants. Recent research of creativity in adults calls for a need to return to the natural, playful, inquisitive state of children at play (see \(\text{http://www.imagilab.org}\)\(^4\)). The ELP will also serve as an organizing mechanism for managing a stream of “change management” activities in a company that necessarily parallel a stream of “production systems development” activities.

A schematic of the ELP “concept” is presented in Figure 3. The entry questions serve as the “starting points”. For example, is the company seeking to develop a new production concept, such as mass customization, for a new line of digital products, or is the company more concerned about improving their current production capabilities by limiting the number of production stoppages? Such entry questions will seek to delimit the ELP experience and to activate the “innovation” process. However, in today’s competitive industrial situations, these questions must be connected to the more pressing business problems – supply chain management, product development, the extended enterprise, outsourcing, etc. Typically, the entry questions tend to be specific, so one of the main roles of the ELP will be to enable the participants to establish broader connections to the larger business problem and challenges.

The establishment of these connections is non-trivial and requires innovation and incisiveness. In addition, the interchange between plenary and task force activities is, in practice, a circular process. A creative idea-generation process could be integrated at this step. LEGO’s Serious Play\(^\text{TM}\) (see \(\text{http://www.seriousplay.com}\)\(^5\)) is one such game that is newly available, although similar games have been used by the CIP researchers in the past. Once the connections from the entry questions to the business problems have been established, then the participants would move from the plenary to the Model Building room to explore the development of high-level production “solutions” that were suggested in the plenary sessions. This “Methods and Tools” room would essentially contain both computerized and manual methods to engage the
participants in further “play” intended to foster visualization of production alternatives. Central to the ELP is the development of a computerized Knowledge Management System (KMS), termed RoundTable, that is envisaged as a knowledge repository of case-based reasoning, simulation, visualization, games, videos, virtual plant tours, etc. designed to contain and capture “resilient” industry knowledge. RoundTable serves as a metaphor for the collaborative, knowledge sharing effort that is the genesis of the ELP.

The third connected room in the ELP is designed as a “Resource Library” or a “Knowledge Café” that would provide visual exemplars of company products, stories of successful strategic developments, books, tapes, etc. The layout of the room will foster “informal” interactions among the participants that are vital to the creation of a “collaborative” dialog process.

At the end of the day, the aim is to have developed a “shared picture” of the future state of production among the participants that has undergone some preliminary high-level evaluations. The decision space will undergo an expansion of ideas followed by a consensual contraction/selection of the most promising solutions. “Post-processing” focus groups will most likely be activated with “action items” to be completed by the next seminar.

**Experimental Laboratory for Production (ELP)**

![Diagram of ELP](image)

**Figure 3. “Concept” of the Experimental Laboratory for Production (ELP)**
While the above discussion outlines a brief perspective on the nature of the ELP, what of its’ contextual placement between the industry and the university, and what are the nature of its’ interactions and knowledge flows with industry? Figure 4 depicts the ELP placed in a context between industry and the university. While Figure 4 provides a graphical illustration of the positioning of the ELP, what would be the nature of the process interactions and directions of the knowledge flows. Figure 5 is an attempt at portraying these process interactions and “knowledge flows” in the ELP.

As seen from Figure 5, the knowledge process moves from the theoretical on the left hand side to the practical on the right hand side. Typically, an industrial company may approach a university to perform some specific research. In the case of the ELP, the research focus involves some aspect of production. This research tends to be of a 1 to 1 mapping in that a Ph.D. project would be formulated in the CIP and “action research” would begin in that company. The cumulative knowledge gained from the different Ph.D. projects conducted by the CIP eventually enables a more generic research to be performed, i.e. a 1 to many mapping of production knowledge. This generic production knowledge could then be translated to companies through the ELP. As individual companies approach the ELP with specific entry questions, e.g. how do we implement mass customization?, the connection to the larger business problem could be established through the participative, facilitative process of the ELP. The ELP will assist industrial companies in moving from a specific view to a more holistic view. The specific entry questions eventually lead to a knowledge mapping of a many to 1, and will assist in inspiration, problem solving, developing guidelines, determining/evaluating best practices, etc. for a specific company.

**Figure 4. Positioning of the ELP between Industry and the University**
A key component of the ELP in this industry/university context is the underlying building block of education and Aalborg University’s Problem-Based Learning paradigm. With its access to numerous company project teams of students from the Master’s and B.S. programs in the Department of Production at Aalborg University, some novel research ideas, methods, or tools regarding process or content could be “tested” or “evaluated” in a laboratory environment. While actual performance in an industrial setting will most likely vary, this testing or evaluation serves to provide some preliminary indications of the suitability of the idea, method, or tool and will undoubtedly lead to more meaningful prototyping. In addition, the Master’s in Management of Technology (MMT) Program provides opportunities for industry to further enhance their production knowledge. As the looped arrows indicate, not only is there knowledge creation and transfer from research to the practical, but also there is a feedback from the pragmatic to the theoretical. The next section presents the requirements of the Knowledge Management System (KMS) that is a key component of the ELP.

3. *RoundTable*: A Knowledge Management System (KMS) to Facilitate Strategic Development in Production Organizations

3.1 Background on Knowledge Management

There is no one universally accepted definition of “knowledge management”. Turban and Aronson⁶ (p. 356) define knowledge management (KM) as a “set of processes for transferring intellectual capital primarily residing as tacit knowledge in individuals, localized groups, within the organization, and the geographically dispersed branch offices of an organization to value processes that lead to innovation, knowledge creation, and replenishment of the organization’s core competency.” Knowledge is dynamic and is shared information that is contextual, relevant, and actionable. Knowledge differs from data and information in that it conveys meaning. For an industrial enterprise, the goals of a KM initiative would be to transform knowledge to add value to business processes and operations, leverage knowledge strategic to the business to accelerate growth and innovation, and use knowledge to provide a competitive advantage for the firm (Turban and Aronson⁶).

3.2 Knowledge Components of *RoundTable*

The basic building blocks of a Knowledge Management System (KMS) are a knowledge repository, knowledge contribution and collection processes, knowledge retrieval systems, a knowledge directory, and a method for content management. *RoundTable* is being developed as a Web-based prototype KMS to facilitate strategic development and innovation for production organizations. The term, *RoundTable*, is used to invoke the imagery of a participative, sharing dialog. As Figure 6 conceptualizes, this KMS prototype will contain technical components dealing with both process and content knowledge for production.

For the *RoundTable* knowledge repository, one of the key technical components will be a Case-Based Reasoning (CBR) tool. The main idea of CBR is to adapt solutions that have been used to solve old problems for use in solving new problems. A CBR tool has facilities for retrieving, reusing, revising, and retaining cases. In the context of the ELP, CBR will be used to manage cases dealing with various production issues, such as planning, inventory, scheduling, etc.
Figure 5. Modeling Knowledge “Flows” in the Experimental Laboratory for Production (ELP)
Retrieval of a case may point to certain methods or tools that were effectively used to solve a previous, similar production problem.

Visualization is a key aspect to the creative development of a production strategy, so various modes, such as videos, pictures, animations, games, simulations, etc. will be incorporated in the knowledge repository of RoundTable.

---

**RoundTable: A KMS for Production Strategy Development**

---

3.3 *RoundTable* Prototype

The initial screen of the *RoundTable* prototype is displayed in Figure 7. Note that the production knowledge is organized around a five-phase systematic strategic management process as described in Riis and Johansen¹. While the “break-points” may not be as clearly identifiable in reality, nevertheless, the five phases are sufficiently distinct to assist with organizing production systems knowledge. A “warm-up” phase is introduced to assist with sparking creativity. Pictorial icons of business metaphors easily guide the user or the facilitator around a conversational “dialog” process. Each picture icon leads to another phase of the process that includes more production knowledge content.
For example, Figure 8 displays a screen design of “Phase 2: External Trends and Strategic Challenges.”

**Phase 2: External Trends and Strategic Challenges**

- Develop a shared picture of the need for change
- Develop a common picture of external and internal trends
- Assess the present mode of operation

**Definition**

What is this Phase about? Creating an organizational shared picture as regards the need for change, external trends and the strategic challenges of the enterprise (Riis and Johansen, 2000).

**Methods**

- Nominal Group Technique (NGT) definition example
- World Map definition example
- Problem Matrix (Riis, 1994) definition example

**Critical Issues**

- Personnel
- Time
- Financial

**Project Workbook**

**Case Library**

**Videos**

**E-learning**

**Figure 8. RoundTable Screen Design**
Note the inclusion of a Project Workbook module. This module will serve as a repository of raw knowledge that is generated by the participants in a collaborative production strategy development session. For example, meeting notes, timelines, presentations, spreadsheets, etc. would be included and made available to strategy participants. An e-Learning module could contain informative tutorials on fundamental production concepts, such as agile or lean manufacturing, that strategy participants would be able to access outside the session so as to continue their “learning”. It is envisaged that the knowledge stored in RoundTable regarding production ideas, methods, and tools would not be static, but would be periodically reviewed and updated as more interactions occur with industry and as more Ph.D. projects are completed.

4. A Research Agenda for the ELP

This paper presents some preliminary ideas for the development and operation of the ELP. Some building blocks exist; however, many more remain to be developed. Specifically, these building blocks can be categorized as process or content related and help to establish a research agenda for the ELP.

In the area of content support, the following are the needs of the ELP:

- Case-Based Reasoning (CBR) module
- High-level graphical simulation module
- Further refinement and development of generic production concepts and a universal function translator for production concepts to other business functions
- E-learning modules
- Project Workbook
- Continued development of methods/tools for production strategy

In the area of process support, the following are the needs of the ELP:

- Methods for facilitating organizational change
- Methods/guidelines for process facilitation
- Visualization techniques for production concepts
- Methods for initiating and enhancing creativity

It is envisaged that the RoundTable KMS would be used in three different operational modes. These modes may be defined as Inspiration, Exploration, and Search. Figure 9 graphically displays the conceptual use of the various modes. The Inspiration mode is intended to facilitate a consensual, team building approach to developing a strategic vision for the future state of production. The Exploration mode is being designed to enable users to seek alternative theories, methods, and tools that may facilitate production knowledge sharing. Finally, the Search mode is intended to foster the process of obtaining specific solutions for the company’s contextual situation. While the “language” or dialog process in the Inspiration mode will tend to make use of general metaphors or analogies, it is envisioned that the language in the Exploration and Search modes will tend to utilize specialized manufacturing terminology.
5. Further Remarks

Consistent with the CIP framework, the ELP is intended to serve as a natural bridge between Danish industry on the one side and the various CIP Ph.D. projects on the other side. As Figure 6 depicts, a number of research projects involving case-based reasoning, visualization, simulation, process facilitation, etc. are being initiated and will be integrated into the Round-Table Knowledge Management System. This KMS will serve a key role in the implementation of the overall ELP concept. Integration of the change management process with production systems development will be emphasized.

Strategy development is an innovative, creative process that has long-term impacts for a company. The ELP, a novel concept for production strategy innovation and development, will serve to spark creative management systems solutions to industrial challenges for Danish companies and contribute to the vitality and evolution of production knowledge.

Acknowledgements

The authors acknowledge the contributions of the participants from the Production Strategy group during the CIP Seminar held on 9 October 2001.
Bibliography


[4] Imagination Laboratory (http://www.imagilab.org)


Biographies

JAMES T. LUXHØJ is Associate Professor of Industrial and Systems Engineering at Rutgers University. In 1994-95 and Fall 2001 he was a Visiting Professor at Aalborg University in Denmark. He received his Ph.D. in industrial engineering and operations research from Virginia Polytechnic Institute and State University in 1986. Dr. Luxhøj served as the Principal Investigator on a Federal Aviation Administration (FAA) research grant to develop an intelligent decision support system for aviation safety analysis and is currently serving as the Principal Investigator to develop analytical methods for aviation safety risk modeling, assessment, and management. He has published extensively on topics such as risk analysis, reliability and maintenance modeling, econometric modeling, and decision support systems. Dr. Luxhøj serves as a Department Editor for IIE Transactions on Operations Engineering, and as Associate Editors for Journal of Design and Manufacturing Automation and the Journal of Engineering Valuation and Cost Analysis. He will be a co-author of the book Engineering Economy, 12th edition with William G. Sullivan and Elin M. Wicks. Jim resides in Somerset, New Jersey with his wife and two children.

JENS O. RIIS is a Professor of Industrial Management Systems at the Department of Production, Aalborg University, Denmark. He holds an M.Sc. in Mechanical Engineering from the Technical University of Denmark and a Ph.D. in Operations Research from the University of Pennsylvania, USA. His main teaching and research areas are design of production management systems, technology management, project management, and integrated production systems. Prof. Riis has recently headed two research programs in integrated production systems and technology management, and is now Deputy Director of a new research Center for Industrial Production at the Aalborg University. He is a member of the IFIP Working Group 5.7 on Integrated Production Management and of the international editorial board of several international journals.

JOHN JOHANSEN is a Professor of Production Control and Planning and Supply Chain Management at the Center for Industrial Production, Aalborg University, Denmark, and Director of the same center. He holds a M.Sc. in Engineering and a Ph.D. in Industrial Management from the Aalborg University. His main areas of teaching and research are Production Management, Production and Material Control, and Supply Chain Management.

CLAUS M. BALKEN holds a BSc in Civil Engineering and a BSc in Computer Science from Aalborg University supplied with a management education from INSEAD. After 15 years of industrial experience he is now working as a management consultant and also part time with the Center for Industrial Production at Aalborg University as an associate research professor. His current research interest is experimental design of production systems.
HENRIK JØRGENSEN is a Ph.D. student at the Center for Industrial Production, Aalborg University, Denmark and holds a M.Sc. degree in Industrial Management Systems. His research area is concentrated on the process of developing operations strategies for industrial companies, and he is currently engaged in a research project with the Danish pump producer Grundfos. Formerly, he was a management consultant with PA Consulting Group and completed studies abroad at the University of Wisconsin-Madison and Massachusetts Institute of Technology.