WP4 – Planning and control of intelligent operations
Executive summary

Work package 4 aims to develop new control concepts and models for use in real time operational settings which replace the traditional MRP logic. Innovations in ERP systems and execution systems are required to enable automated and intelligent operations in the factory and throughout the supply chain. The work package will produce high quality scientific results and high performance within the following:

- New theories, frameworks, methods and tools
- Publications, workshops and meetings
- International cooperation and mobility
- Industrial cases and demonstrators

New theories, concepts and frameworks have been developed in collaboration with the industrial partners. The research strategy (mainly action research and case studies) has contributed to a fruitful research arena where ideas and initiatives have been cultivated into focused research activities. The successful research strategy will be adopted in the future activities. We have managed to develop and implement a publication strategy and culture which now leads to promising results. The publication activities are very good and are increasing. The main priority is to publish in recognized journals.

Several initiatives contribute to a very satisfying improvement in international collaboration and mobility. It is satisfying to report that we have recently hosted the 13th international conference in "The Modern Information Technology in the Innovation Processes of the Industrial Enterprise" (MITIP) with representatives from 15 different countries. The conference resulted in important international contacts as well as a conference proceeding with a double blind review process giving us valuable publication points. There have been meetings, seminars, and co-publications. The ongoing industrial cases continue to develop knowledge and solutions for the active industrial partners, including Volvo Aero Norge, Teeness, Tine, Pipelife, Kongsberg Automative, and Benteler. Methods, guidelines, process improvements, strategic advice and analyses, and tools are some of the deliveries to our industrial partners. As a major focus of Norman, the PhD students are strongly connected to the industrial cases in their research projects and provide an important part of these deliveries. The PhD students in WP4 are Daryl Powell and Emrah Arica.

A central aspect of WP4 is exploring the relationships between lean production and information technology (IT). Therefore, in this executive summary, we choose to highlight the results generated in this area of WP4.

Beyond the paradox: ERP support for Lean Production

Though the just-in-time principle is well understood, the relationship between IT and lean production remains a controversial and far less explored topic. While lean is often characterized by decentralized coordination and control, IT is typically best suited to support centralized production planning. WP4 aims to provide illustrative frameworks and models in order to explore the topic. As such, some examples of the work carried out within WP4 have been the development of a conceptual framework for ERP support for lean production principles (Figure 1), and a capability maturity model (CMM) for ERP support for pull production (Figure 2).
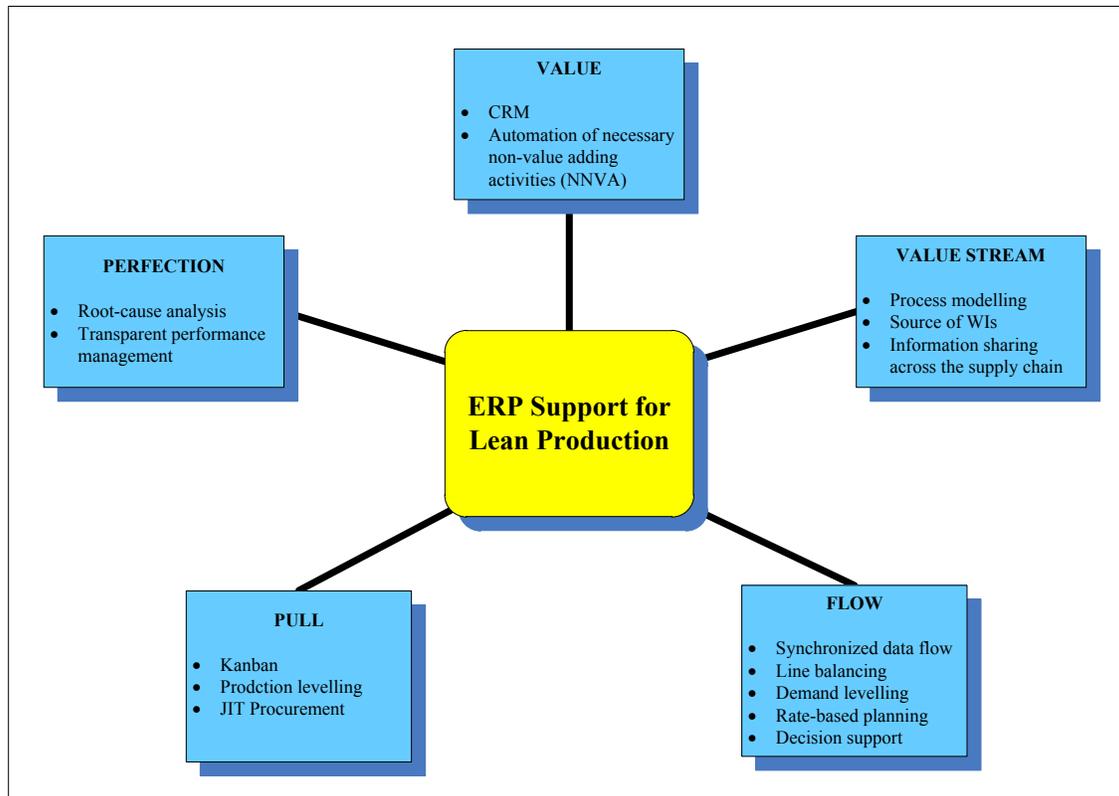
Figure 1: ERP Support for Lean Production – a Conceptual Framework (Powell et al., 2011)

By operationalizing each of the five lean principles with practical examples, it was possible to identify the potential support functionality offered by a contemporary ERP system for lean production. This framework can be used by practitioners in order to setup an ERP system to effectively support lean production principles. We suggest that this is especially useful for small- and medium-sized enterprises, which often have a challenging task in applying either of these two approaches to production management.

Empirical findings also suggested that more research was required in order to investigate ERP support functionality for pull production practices; therefore four case studies were conducted in the Netherlands in order to develop a capability model which can be used by practitioners to integrate ERP systems with pull production.

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**ERP Support for Pull Production:
Capability Maturity Model**

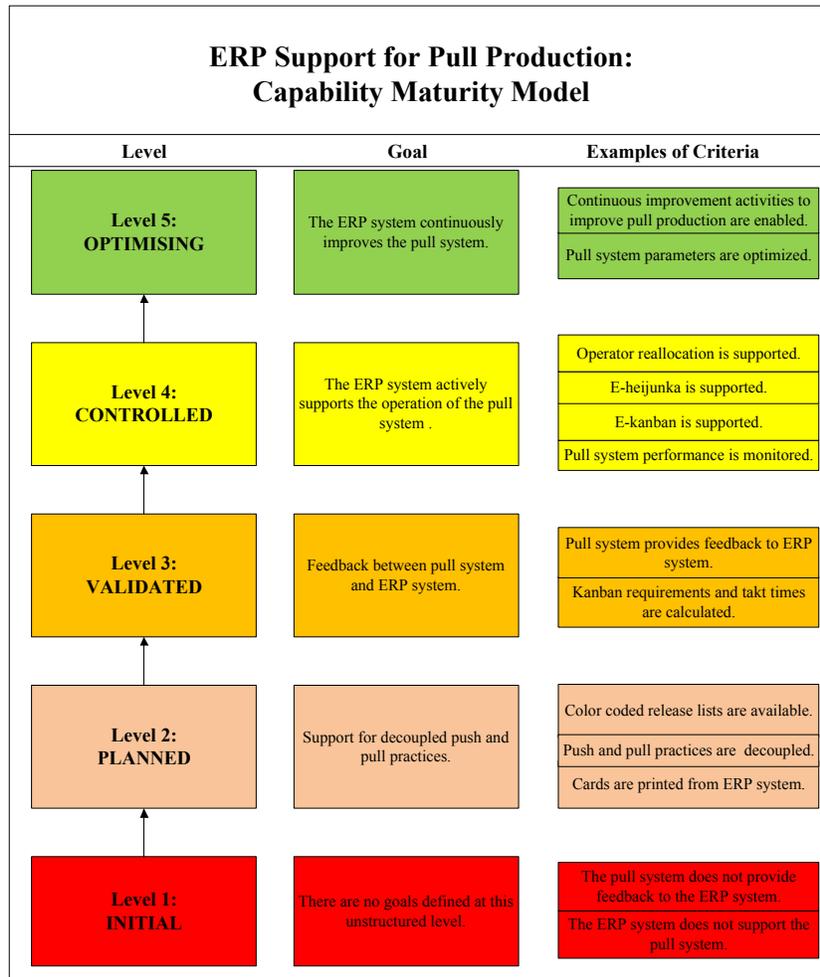| Level	Goal	Examples of Criteria
Level 5: **OPTIMISING**	The ERP system continuously improves the pull system.	Continuous improvement activities to improve pull production are enabled. Pull system parameters are optimized.
Level 4: **CONTROLLED**	The ERP system actively supports the operation of the pull system .	Operator reallocation is supported. E-heijunka is supported. E-kanban is supported. Pull system performance is monitored.
Level 3: **VALIDATED**	Feedback between pull system and ERP system.	Pull system provides feedback to ERP system. Kanban requirements and takt times are calculated.
Level 2: **PLANNED**	Support for decoupled push and pull practices.	Color coded release lists are available. Push and pull practices are decoupled. Cards are printed from ERP system.
Level 1: **INITIAL**	There are no goals defined at this unstructured level.	The pull system does not provide feedback to the ERP system. The ERP system does not support the pull system.

Figure 2: ERP Support for Pull Production: Capability Maturity Model (Powell et al., 2012)

The examples given in the CMM also represent examples of innovations in the use of ERP systems to enable automated and intelligent operations in the factory.

International collaboration

Research collaboration, cooperation, and co-publishing in an international context are also important aspects of WP4. Examples of our international collaboration partners include:

- University of Groningen, Netherlands
- Newcastle University Business School, UK
- University of Aalborg, Denmark
- University of Bergamo, Italy
- Aalto University, Finland
- Chalmers, Sweden

MITIP 2011 – International scientific conference

- One of the major successes of WP4 in 2011 was to host the international conference, "The Modern Information Technology in the Innovation Processes of the Industrial Enterprise", in the MITIP series.

- The conference attracted and gathered more than 60 international participants from leading academia and research, as well as formed a fruitful discussion platform for recent developments and trends in ICT enabled manufacturing and supply chains

- 47 papers, all peer reviewed, with participants from 15 different countries representing 3 regions (USA, Europe, and Asia) were represented.

- The proceedings were published by Tapir Academic Press, as the first volume of Engineering Series at Faculty of Engineering Science and Technology (IVT)

Publications

A selection of the publications generated from WP4 are:

Bakås, O; Govaert, T; Landeghem, H.V. 2011. Challenges and success factors for implementation of lean manufacturing in European SMEs. *In Dreyer, H., Strandhagen, J. O., & Bjartnes, R. (eds), Proceedings of MITIP 2011*. NTNU Engineering Series, Tapir Academic Press, Trondheim.

Bohlin, R.A; Arica, E. 2011. Virtual integration and control of supply chain in ship projects. *In Dreyer, H., Strandhagen, J. O., & Bjartnes, R. (eds), Proceedings of MITIP 2011*. NTNU Engineering Series, Tapir Academic Press, Trondheim.

Goeldner, T., & Powell, D. 2011. The Use of Information Technology in Lean Production: Results of a Transnational Survey. *In Dreyer, H., Strandhagen, J. O., & Bjartnes, R. (eds), Proceedings of MITIP 2011*. NTNU Engineering Series, Tapir Academic Press, Trondheim.

Hvolby, HH; Steger-Jensen, K; Alfnes, E; Dreyer, H. 2011. Collaborative Demand and Supply Planning Networks. *In MM Cruz-Cunha & J Varajão. (eds), Enterprise Information Systems Design, Implementation and Management: Organizational Application.* IGI Global, New York

Netland, T; Alfnes, E. 2011. Proposing a Quick Best Practice Maturity Test for Supply Chain Operations. *Measuring Business Excellence*, 15, pp 66-76

Powell, D., Alfnes, E., Strandhagen, J. O. & Dreyer, H. 2011. ERP support for lean production. *APMS 2011: International Conference on Advances in Production Management Systems*. Stavanger, Norway. 26-28 September 2011: Springer.

Powell, D. & Strandhagen, J.O. 2011. Lean production vs. ERP systems: an ICT paradox? *Operations Management*, 37 (3) pp 31-36,

Powell, D. & Olesen, P. 2011 ERP Systems for Lean Production Control. *In Dreyer, H., Strandhagen, J. O., & Bjartnes, R. (eds), Proceedings of MITIP 2011*. NTNU Engineering Series, Tapir Academic Press, Trondheim.

Powell, D., Riezebos, J. & Strandhagen, J. O. 2012. Lean production and ERP systems in SMEs: ERP support for pull production. *International Journal of Production Research*, Available online 23 January 2012.

Sletten, L. & Powell, D. 2011. Lean vs IT: Effective Production Control and Performance Management with Dashboards. *In Dreyer, H., Strandhagen, J. O., & Bjartnes, R. (eds), Proceedings of MITIP 2011*. NTNU Engineering Series, Tapir Academic Press, Trondheim.

Strandhagen, J.O; Dreyer, H.C; Romsdal, A. 2011. Control Model for Intelligent and Demand-Driven Supply Chains. In Flynn, B; Morita, M; Machuca, J. (eds),Managing Global Supply Chain Relationships: Operations, Strategies and Practices. IGI Global, New York

Contribution to education

Besides the focus on research and industrial developments, WP4 has also generated significant contributions in education through a number of student projects and master theses.

• Alexey Lekanov (2011): Logistics Planning Module for Microsoft AX: Demand Planning. Project thesis in Engineering and ICT at the Department of Production and Quality Engineering (forthcoming)

• Anders Lerberg (2011): Logistics Planning Module for Microsoft AX: Supply Chain Order Management. Case Kongsberg Maritime. Project thesis in Engineering and ICT at the Department of Production and Quality Engineering (forthcoming)

• Djuro Topalovic (2011): Logistics for a sustainable fresh food sector: solutions for environmental and resource efficiency – with special focus on application of modern collaboration and information sharing models. Case TINE. Project thesis in Global Technology Management at the Department of Production and Quality Engineering (forthcoming).

• Jens Kristian Klungseth (2011): Dynamic sales and operations planning for coordinated mass- and spare parts production in the automotive industry. Case Benteler. Project thesis in Mechanical Engineering at the Department of Production and Quality Engineering (forthcoming)

• Johansen, Øyvind Ketil (2011) Logistics Planning Module for Microsoft Dynamics AX: Inventory Planning. Master thesis in Engineering and ICT at the Department of Production and Quality Engineering.

• Linda Sletten (2011): Performance management using business intelligence. Case Noca. Master thesis in Engineering and ICT at the Department of Production and Quality Engineering (forthcoming).

• Møller, Alexander (2011) Logistics Planning Module for Microsoft Dynamics AX: Supply chain order management. Master thesis in Engineering and ICT at the Department of Production and Quality Engineering.

• Sindre Grindheim (2011): Dynamic and distributed production control. Case Volvo Aero. Project thesis in Engineering and ICT at the Department of Production and Quality Engineering (forthcoming)

• Student project "Supply Chain Management at TINE", in the master course TPK4160 Value chain control and applied decision support.

• Svendsen, Ole-Johan Øby (2011) Decision support for S&OP and Production Sequencing. Master thesis in Mechanical Engineering at the Department of Production and Quality Engineering.

• Terje Bye (2012): Planning and control in fresh food manufacturing. Case TINE. Master thesis in organization and management at the Department of Production and Quality Engineering (forthcoming).

• Yngve Mongstad (2011): Visual logistics analysis in the aluminum industry. Case Hydro Aluminium. Project thesis in Mechanical Engineering at the Department of Production and Quality Engineering (forthcoming)

• Yoana Milazzo (2011): Dynamic (real-time) scheduling on the shop-floor. Case Volvo Aero. Project thesis in Engineering and ICT at the Department of Production and Quality Engineering (forthcoming)

• Yong Zhou (2011): Logistics for a sustainable fresh food sector: solutions for environmental and resource efficiency – with special focus on use of technology and different control principles. Case TINE. Project thesis in Global Technology Management at the Department of Production and Quality Engineering (forthcoming).

• A continuing education course in Lean production for 20 students