

INTEGRATING FLOW EFFICIENCY, RESOURCE EFFICIENCY AND AUTOMATION COMPETENCE IN SECONDARY WOOD PRODUCTS MANUFACTURING: A CASE STUDY FROM SWEDEN

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Abstract:

Secondary wood products manufacturers often struggle to balance resource efficiency and flow efficiency, resulting in fragmented production systems and limited responsiveness to customer needs. This case study examines improvement potential in a Swedish wood-based manufacturing firm by analysing the value flow from supplier delivery to customer delivery. Observations, interviews, workshops and value flow analysis were used to identify major sources of waste, organisational barriers and opportunities for automation. A future production mode is proposed that integrates improved supplier collaboration, redesigned physical flow and strengthened internal competence in robotics. The study contributes a structured assessment approach for small wood-based manufacturing firms and demonstrates the importance of combining technical and organisational development to achieve higher total efficiency.

Key words: value flow analysis; wood-based industries; production development.

INTRODUCTION

Wood-based industries are undergoing rapid transformation driven by increased demand for sustainable materials, higher customer expectations and pressure to improve productivity. While primary wood processing has achieved high levels of efficiency, secondary wood products manufacturing remains characterized by craft-based knowledge (Ray et al. 2006), fragmented production flows and slow adoption of systematic improvement practices (Pirraglia et al. 2009). More recent research indicates that these challenges persist, with lean implementation in secondary wood manufacturing still constrained by organisational and knowledge-related barriers (Abu et al. 2021). Nevertheless, secondary wood products manufacturing constitutes a vital link in the forest-based value chain.

Lean production defines value as what the customer wants from a process (Liker 2009). Achieving high total efficiency requires balancing resource efficiency and flow efficiency (Modig and Åhlström 2015). A unilateral focus on either dimension leads to inefficiencies such as “efficient is-lands” or “efficient oceans”.

Automation, defined as processes controlled by numerical control systems, is increasingly relevant for wood-based industries. Emerging robotic platforms and broader analyses of automation in forest-based sectors indicate that automation is gradually entering craft-based timber and wood production. However, effective adoption depends not only on technical capabilities, but also on infrastructure readiness, data-driven control, sensor-enabled monitoring, operator competence and tacit human expertise (Wagner et al. 2020; Allott et al. 2020; Miltenburg 2005).

Research on forest operations efficiency shows similar challenges upstream in the forest-based value chain, where flow variability, machine utilization and operator competence strongly influence total efficiency. These parallels underscore the relevance of studying efficiency in secondary wood manufacturing (Allott et al 2020).

Research Question

How can a secondary wood products manufacturer increase total efficiency by integrating improvements in resource efficiency, flow efficiency and internal automation competence?

Aim and Contribution

The aim of this study is to map the current production mode, identify areas of improvement, and propose a future production mode. The contribution is twofold:

1. A structured assessment method for improvement potential in small wood-based manufacturing firms.
2. A combined technical organisational perspective on automation adoption in craft-based production.

Parts of the present study build on previously published work. Resource efficiency in the production cell included in this case study has been analysed and reported in an earlier publication (Blomqvist et al. 2017a). Furthermore, the causes of downtime in the same production environment have been examined in a separate study (Blomqvist et al. 2017b). A third study has addressed influencing factors for enabling automation in wood furniture production (Johansson et al. 2016). Together, these prior contributions provide the empirical foundation for the current manuscript, which focuses on flow efficiency and its integration with automation competence.

THEORETICAL FRAMEWORK

Resource Efficiency and Flow Efficiency

Resource efficiency focuses on maximizing utilization of machines and labor, often measured through OEE (Bicheno et al. 2011). Flow efficiency focuses on minimizing throughput time for a flow unit (Mocig and Åhlström 2015). High total efficiency requires balancing both.

Value Flow Analysis in Wood-Based Industries

Value flow analysis maps material flows to identify waste and improvement potential (Petersson et al. 2009). It is increasingly used in wood products manufacturing to reduce transport, storage and quality losses.

Automation Adoption and Tacit Knowledge

Automation adoption in small manufacturing firms is often constrained by tacit knowledge (Sjöberg and Höglund 1997), limited formal training and dependence on external specialists (Rodrigues and Child 2010). Successful adoption requires internal competence development and knowledge transfer.

MATERIAL, METHOD

Research Design

A qualitative case study design was used to investigate one production flow in detail.

Data Collection

Data collection included:

- On-site observations at multiple times.
- Semi-structured interviews with production staff, management and automation specialists.
- A workshop with employees and management to validate observations.
- Interactive discussions with automation specialists were conducted.

Data Analysis

Data were analysed through:

- Value flow mapping.
- Thematic analysis.
- Joint development of a future production mode.

Information flow was not included, as the study focused exclusively on physical flow efficiency.

Validity and Reliability

Triangulation of observations, interviews and workshop data strengthened validity.

Reliability was supported by repeated observations and respondent validation during the workshop.

Ethical Considerations

No personal or sensitive data were collected. All participants consented to interviews and observations.

RESULTS: CURRENT MODE

Organisational Conditions

Interviews revealed limited formal training and inconsistent knowledge transfer. Staff reported repeated disturbances caused by poor incoming material quality and expressed frustration that management did not act on this information.

Technical and Flow Conditions

The current value flow is illustrated in Fig. 1, showing fragmented material movements, multiple transports and several intermediate buffers, which reduce overall flow efficiency. Fig. 2 presents the value flow within the production cell where the products are processed. Fig. 3 illustrates the next processing station, which includes surface treatment and packaging for delivery. A truck transport is required between the production cell and the surface-treatment station.

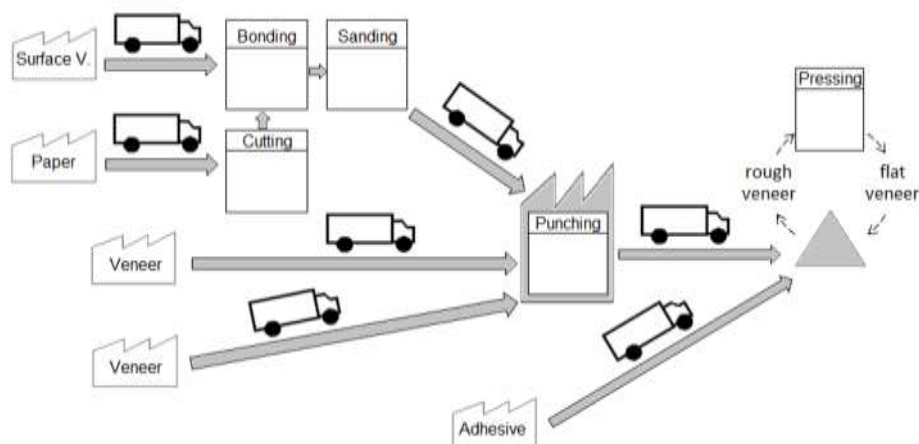


Fig. 1.

Current value flow from suppliers through bonding, sanding, cutting and punching operations.

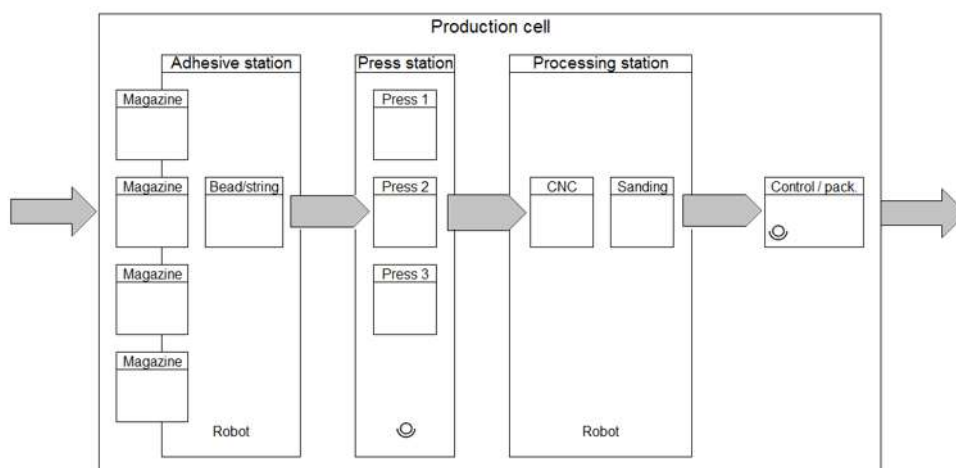


Fig. 2.

Current value flow in the hybrid production cell, including the integrated adhesive station, press station, CNC processing, sanding, and final inspection/packing.

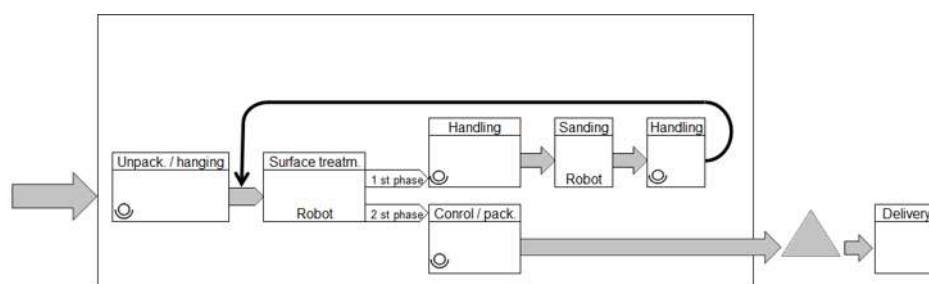


Fig. 3.

Current value flow in the hybrid surface-treatment station, where the products are lacquered and packed prior to delivery.

The production system consists of partially automated islands lacking cohesive flow. Identified non-value-adding activities include:

- Poor incoming material quality.
- Unnecessary lorry transport early in the process.
- Multiple truck transports and interim storage.
- Extensive manual handling.
- Dependence on external robot programming expertise.

These issues reduce both flow and resource efficiency.

PROPOSED FUTERE MODE

The future mode integrates improved supplier collaboration, physical rearrangement of production and expanded automation. Key features include (as illustrated in Figs. 4 and 5):

- Direct delivery of input materials to the production area.
- A unified production cell performing all processing prior to surface treatment.
- Relocation of the production cell adjacent to the surface-treatment station.
- Robots integrated into surface treatment (hanging, sanding, rehanging).
- Reduced manual handling and improved flow continuity.

Further automation is possible if production becomes sufficiently controlled to allow the elimination of intermediate quality checks as illustrated in Fig. 6.

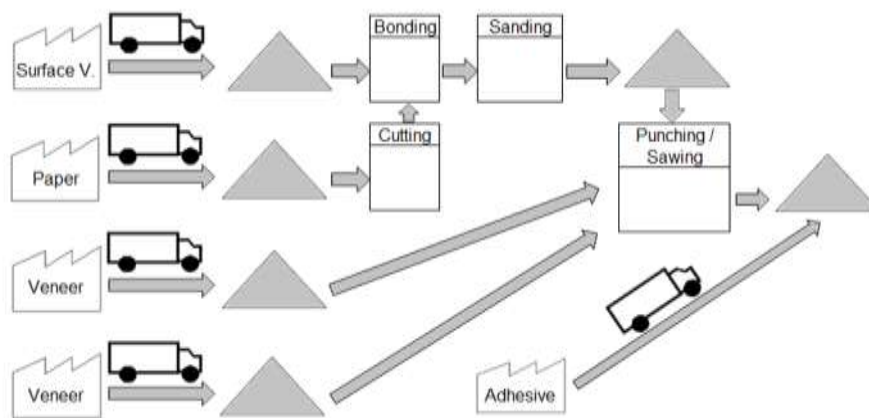


Fig. 4.

Proposed value flow for input and material preparation ahead of production. Interim storage after cutting and bonding is not shown.

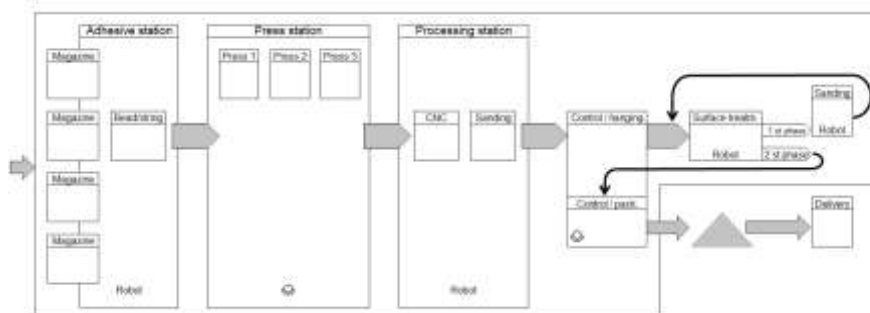


Fig. 5.

Proposed relocation of the hybrid production cell to the hybrid surface-treatment station, which has been further robotized (see the robot performing sanding and handling after the first phase of surface treatment). In addition, several flows have been eliminated through co-location of storage, transport, warehousing, unpacking and hanging.

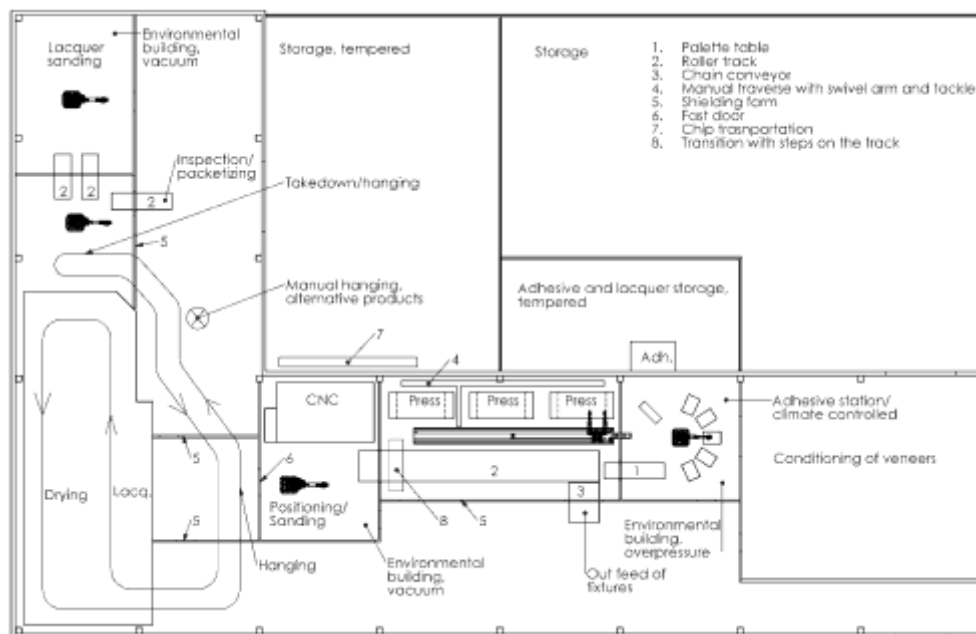


Fig. 6.

Production layout of the desired future mode. This option is further robotized and incorporates climate control in several process steps. For example, incoming materials are conditioned, and cells use vacuum to prevent dust dispersion. Robots handle the presses, perform sanding, load parts into the CNC machine, and hang the product onto the surface-treatment line.

DISCUSSION

Technical-Organisational Integration

The future mode requires significant organisational change. Craft-based knowledge structures may conflict with automation-driven production logic.

Competence Development

The company must decide whether to train existing staff or recruit new automation-skilled employees. Tacit knowledge risks being lost if staff are replaced, since tacit knowledge is embodied, experience-based and difficult to articulate, whereas explicit knowledge is documented, structured and transferable.

Technology Renewal

Existing robots cannot be upgraded to modern control systems, necessitating new investments.

Comparison with Previous Research

Findings align with research on forest operations efficiency, which highlights the importance of flow stability, machine utilization and operator competence. Similar to Rodrigues and Child (2010), this study shows that organisational factors strongly influence technical performance.

Implications for Wood-Based Industries

The case illustrates typical challenges in secondary wood products manufacturing: fragmented flows, tacit knowledge dependence and limited automation competence. The proposed approach can support similar firms in the wood-based sector.

CONCLUSIONS

The study demonstrates that a structured combination of observations, interviews and value flow analysis can effectively identify improvement potential in secondary wood manufacturing. The proposed future mode reduces waste and increases flow continuity. However, organisational development and competence building are essential for successful automation adoption.

Future research should investigate methods for assessing organisational readiness and the creative space available for production development in small wood-based manufacturing firms.

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REFERENCES

- Abu F, Gholami H, Saman MZM, Zakuan N, Sharif S, Streimikiene D (2021) Pathways of lean manufacturing in wood and furniture industries: a bibliometric and systematic review. *Eur. J. Wood Prod.* 79, 753–772. <https://doi.org/10.1007/s00107-021-01713-2>
- Allott J, Canela A, O’Kelly G, Pendergraph S (2020) Data: The next wave in forestry productivity. McKinsey & Company.
- Bicheno J, Holweg M, Anhede P, Hillberg J (2011) Ny verktygslåda för lean (New Toolbox for Lean). Lean Forum, Stockholm, Sweden.
- Blomqvist L, Johansson J, Landscheidt S, Nilson H (2017a). Resource utilization in a production cell for laminated veneer products. *Pro Ligno.* 13. Pp. 142-147. <https://www.proligno.ro/ro/articles/2017/4/BLOMQVIST.pdf>
- Blomqvist L, Nilson H, Johansson J, Landscheidt S (2017b). Downtime causes in a production cell for laminated veneer products. 23rd International Wood Machining Seminar Proceedings, Warsaw, Poland, pp. 28-35.
- Johansson J, Blomqvist L, Nilson H, Landscheidt S (2016). Influencing factors to enable automation of wood furniture production. Proceedings of the 12th meeting of the Northern European Network for Wood Science and Engineering (WSE): Wood science and engineering – a key factor on the transition to Bioeconomy, Riga, Latvia, pp. 208-213.
- Liker JK (2009) The Toyota Way: Lean för världsklass (The Toyota Way: Lean for World-Class Performance). Liber, Malmö, Sweden.
- Miltenburg J (2005) Manufacturing Strategy: How to Formulate and Implement a Winning Plan. CRC Press, Boca Raton, FL, USA.
- Modig N, Åhlström P, (2015) Detta är Lean: Lösningen på effektivitetsparadoxen (This is Lean: Resolving the Efficiency Paradox). Rheologica Publishing, Stockholm, Sweden.
- Petersson P, Johansson O, Broman M, Blücher D, Alsterman H (2009) Lean-Gör avvikelser till en framgång (Lean - Turning Deviations into Success). Part Development AB, Lund, Sweden.
- Pirraglia A, Saloni D, Van Dyk H (2009) Status of lean manufacturing implementation on secondary wood industries including residential, cabinet, millwork and panel markets. *BioResources*, 4, 1341–1358. https://bioresources.cnr.ncsu.edu/BioRes_04/BioRes_04_4_1341_Pirraglia_SV_Lean_Manuf_Secondary_Wood_Markets_593.pdf
- Ray CD, Zuo X, Michael JH, Wiedenbeck JK (2006) The Lean Index: Operational “lean” metrics for the wood products industry. *Wood and Fiber Science*, 38, pp. 238-255. <https://wfs.swst.org/index.php/wfs/article/view/461>
- Rodrigues S, Child J (2010) Private equity, the minimalist organization and the quality of employment relations. *Human Relations*, 63, pp. 1321-1342. <https://journals.sagepub.com/doi/10.1177/0018726709353637>
- Sjöberg L, Höglund M (1997) Handbok i inköp av komplicerad utrustning (Handbook for Purchasing Complex Equipment). Konsortiet Träindustri Kalmar, Linköping, Sweden.
- Wagner HJ, Alvarez M, Kyjanek O, Bhiri Z, Buck M, Menges A (2020) Flexible and transportable robotic timber construction platform - TIM. *Automation in Construction*, 120, 103400. <https://doi.org/10.1016/j.autcon.2020.103400>