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A Case Study of the Ergonomic Consequences of Engineering Decisions

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**A Case Study of the Ergonomic Consequences of
Engineering Decisions**

Human Factors Engineering Lab, Ryerson University

www.ryerson.ca/hfe

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For a more in-depth look on this subject, please see:

Neumann, W.P., Kihlberg, S., Medbo, P., Mathiassen, S.E. and Winkel, J., 2002. A case study evaluating the ergonomic and productivity impacts of partial automation strategies in the electronics industry. *International Journal of Production Research*, 40(16): 4059-4075. <Go to ISI>://000180117700003.

A CASE STUDY OF THE ERGONOMIC CONSEQUENCES OF ENGINEERING DECISIONS

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3- Division of Transportation and Logistics, Chalmers University of Technology, Göteborg

This paper presents a case study of the ergonomic consequences of engineering change. Within the context of a project to re-design an electronics assembly system a decision was made to automate transportation functions. A manual batch-cart system was changed to a line-system with automatic conveyors.

Video analysis of the old and new systems were made and subsequently analysed using a computerised video observation system. These data were combined with production system data obtained from company records and by informal interviews with key informants in the organisation. Detailed examinations of the manual assembly workstations were made as these were most directly affected by the new conveyance system.

The data indicate that the new assembly work has decreased variability of work tasks, decreased cycle time and time available per component insertion, has elements of machine pacing, and decreased available interactions with co-workers. These indicators imply poorer physical working conditions in the new system. This decrease has occurred despite the active involvement of an ergonomics team in the re-design process. The decision to implement the line system resulted from a corporate strategy to increase levels of automation and was made without input from the ergonomics group.

The results of this study suggest that corporate strategy, and subsequent production system design decisions have important implications for ergonomic conditions in the resulting system. Once made, the decision to adopt the line transportation system provided design constraints that could not be entirely overcome by the ergonomics team. Joint-optimisation, through integrated consideration of technical and ergonomic constraints, is necessary to design optimal production systems.

The Ergonomic Consequences of Engineering Decisions

*Evaluating the ergonomic and productivity
consequences of a partial automation strategy.*

Patrick Neumann
Steve Kihlberg
Per Medbo
Jørgen Winkel





Context

- Many Risk Factors Known (eg Bernard 1997 - NIOSH)
- 4% Gross World Product in ill health (WHO:ILO 1998)
 - ~40% WMSDs
- Drive to Increase productivity – Intensification?
- Production Strategies Related to Ill Health
 - 'Downsizing' (Vahtera et al. 1997)
 - 'Lean Manufacturing' (Landsbergis et al. 1999)
 - 'Repetitive Industrial Work' (Norlund et al. 2000)
 - Line systems (Fredriksson et al. 2001, Ólafsdóttir & Rafnsson 1986)

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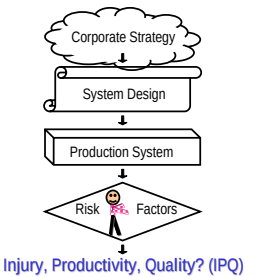
Can we identify the sources of WMSD risk factors in production system design strategies?

- ➔ to identify better production strategies
- ➔ to develop assessment capabilities

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Theoretical Framework



Injury, Productivity, Quality? (IPQ)

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Exploratory Longitudinal Case Study

An Electronics assembly system was re-designed

Before:

'Batch-transport' System



After:

'Line-conveyor' System



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Exploratory Pre-Post Case

- QUANTITATIVE:
 - Production information
 - Video Analysis of Stations (limited sample sizes)
 - Biomechanical Modelling & detailed video of key str
- QUALITATIVE
 - Key Informants
 - Observations from field, video, photos
 - Questionnaires & Interviews conducted

➔ Focus on mechanical loading and production performance

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Strategic Change Process: 2 groups

TECHNICAL GROUP:

1. Automation of Assembly
2. Automation of Transport to Line System

WORK ORGANISATION GROUP:

1. Ergonomic Design of Workstations
2. Work Organisation - to improve working conditions

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System Level Results: Work Changes

Batch



Line



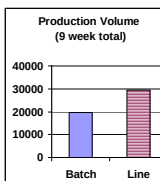
- Manual Work Eliminated:
 - Assembly
 - Framing
 - Transport
- Work Added
 - Robot supervision
 - Forced waiting

Less potential for co-worker interaction & support (↑ risk) ?

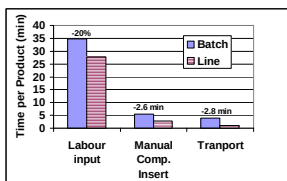
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System Level Results: Productivity

Production Volume (9 week total)



Time per Product (min)



- Increased output
- Increased production variability
- No change in Quality Work

- less labour input
- less manual assembly
- less manual transport
- more expensive workstations

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Workstation Level Results



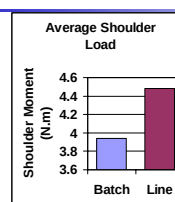
↑ insert rate from 1 every 8.3 sec to 1 every 7.6 sec
(7.9s to 5.2 at full speed= 34% speed-up)

Adjustable workstation (sit-stand capability)

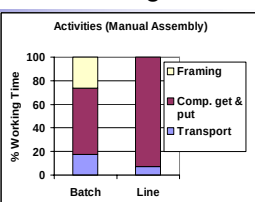
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Workstation Level Results: Ergonomics

Average Shoulder Load



Activities (Manual Assembly)



- Cycle time ↓ 38%
- Arm elevation ↑ 26%

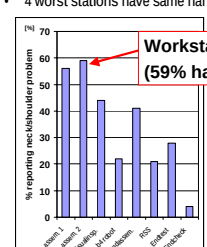
- Decreased task variability
- time in get-put moves >90%

Ergonomic Indicators based on undisturbed production indicate intensification of shoulder loading

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Workstation Level Results: Shoulder Pain

- 4 worst stations have same handling activities



Workstation studied (59% have Shoulder problem)

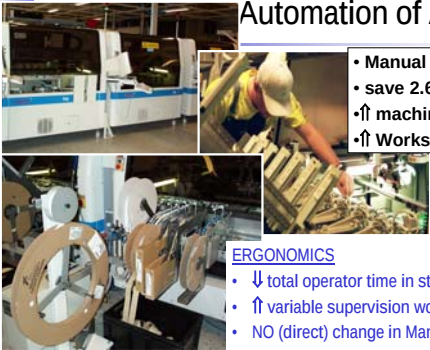
OPERATOR REPORTS:

- New system was very stressful due to work speed and technical problems in the system.
- Operators reported concern about their long term health (burnout & sick leaves)

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•2

Automation of Assembly



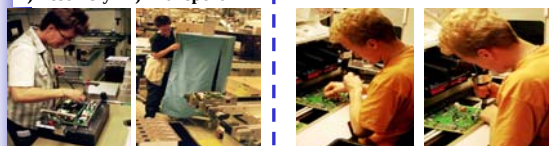
- Manual work ↓
- save 2.6 min / board
- ↑ machine supervision
- ↑ Workstation cost

ERGONOMICS

- ↓ total operator time in stereotyped tasks
- ↑ variable supervision work (reaching?)
- NO (direct) change in Manual Assembly
- BUT... unanticipated consequences ...

Line Automation Strategy

Batch Transport System:	Serial Line System:
1) Assembly 2) Transport	1) Assembly 2) Assembly



- Less 'non-value added' work
- ↓ W.I.P.
- ↑ Disturbances & Losses
- ↓ cycle times (no framing)
- Difficult to expand

- Less task variety
- Machine Pacing
- ↑ Frustration from disturb.
- Increased average shoulder load
- Intensification (workstation level)

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Workstation Design Strategy



Constraints from tech. team:

- Conveyor pathway & space
- Line rate & tasks
- Number of parts (increased)

- 1st rack elevates parts above transport system (↑ load)
- 2nd rack added for failed automation parts (↑ load)

• Adjustable 'Ergonomic' workstation (sit-stand capability):

- expensive & not used much
- does not change essential shoulder demands

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Strategy: Work Organisation

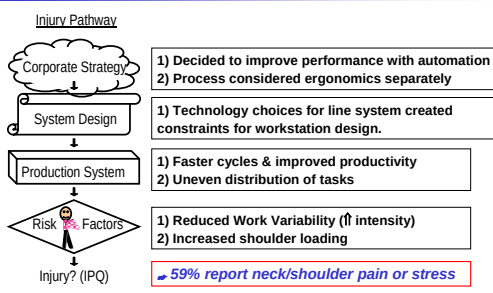
- USED: Partial rotation, unstructured
- Some operators had 'specialised' jobs (hi variability)
- Work Org. team planned rotation to balance load
- New manager rejected Work Org Strategy
 - Temporary operators being used
 - Could be eliminated with further automation
 - Didn't warrant investing in multiskilling (?)

⇒ Operators' workload unevenly distributed

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Case Study Illustrates Linkages to Injury

Injury Pathway



Production system level

- Corporate Strategy
- System Design
- Production System

Workstation level

- Risk Factors
- Injury? (IPQ)

1) Decided to improve performance with automation
2) Process considered ergonomics separately

1) Technology choices for line system created constraints for workstation design.

1) Faster cycles & improved productivity
2) Uneven distribution of tasks

1) Reduced Work Variability (↑ intensity)
2) Increased shoulder loading

59% report neck/shoulder pain or stress

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Case Study Conclusions

1. Productivity and Ergonomic objectives coincided in automating repetitive assembly work (*workforce level*) but...
 - Unanticipated problems in automation constrained workstation design with negative ergonomic consequences
2. Productivity and ergonomics were in conflict in the automation of transport work
3. Strategic decision makers and engineers set early constraints for operator physical loading

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•Neumann et al. 2001, PREMUS, Amsterdam, NL

Productivity - Ergonomics Relationships

		Ergonomics		
		Better	No Change	Worse
Productivity	Better	<u>Go!</u>	OK	\$ + pain
	No change	OK	↩	X
	Worse	Hidden Gains?	X	X

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