Managing Risk in the Innovation Process

W.P. Neumann

Human Factors Engineering Lab, Ryerson University, Toronto, Canada
"The greatest improvement in the productive powers of labour… seem to have been the effects of the division of labour”

-ADAM SMITH (1776)

Chapter 1: ’The Wealth of Nations’

✓ The Pin Factory Example
And the race was on…

- Talyor (1911) – *Scientific management*
- FORD (1920’s)
- Demming (1950s +) – *Continuous Improvement*
- TOYOTA (1970 +)
- Womack (1994) – ’Lean’
- 2000+ ”*Lean Sigma*”: ”*Waste*” Elimination
Engineered systems are largely immune from change
Change gets harder throughout design

EASE OF CHANGE

[Miles and Swift, 1998].
OLD
’DOCK’ Station

NEW
’LINE’ System

(Neumann et al., 2006, IJOPM)
What is the problem?

Risk Factors

↓

Disorders

(Neumann et al., 2006, IJOPM)
What is the Problem?

Production System

↓

Risk Factors

↓

Disorders

(Neumann et al., 2006, IJOPM)
OLD SYSTEM:

(Neumann et al., 2006, IJOPM)
What is the source of the problem?

- System Design
- Production System
- Risk Factors
- Disorders

(Neumann et al., 2006, IJOPM)
WHO IS RESPONSIBLE?

NO ONE!

Workplace is an EMREGENT Characteristic of design

(Neumann et al., 2006, IJOPM)
PRODUCT DESIGN EXAMPLES
Product Design Can Define Postures
Strategies

Product Design

System Design

Production System

Risk Factors

Outcomes

(Neumann et al., 2006, IJOPM)
Ergonomics is an “emergent” characteristics (Neumann et al., 2006, IJOPM)
Examples of analysis situations - Buss

50%ile male mounting air pipe under crossbeam

Eye view

Sundin 2000, IEA
AUTOMATION EXAMPLE
Automation of Assembly

Less manual work
save 2.6 min / board
++ machine supervision
++ Workstation cost

ERGONOMICS
less total operator time in stereotyped tasks
more variable
Some awkward postures

(Neumann et. al, 2006, IJPR)
Automation Failure -> machine paced manual work

- Adjustable ‘Ergonomic’ workstation (sit-stand capability):
  - repetition + 38%
  - Arm elevation + 26%

(Neumann et. al, 2006, IJPR)
The Sources of Risk Run Deep…

Injury Pathway

Corporate Strategy

System Design

Production System

Risk Factors

Injury?

59% report neck/shoulder pain or stress

Comment

1) Improve Performance with Automation
2) Consider Ergonomics separately

1) Technology choices for line system
2) Workstation design constrained by tech.

1) Increased rate, machine pacing elements
2) Fewer tasks, less interaction potential

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

(Neumann et. al, 2006, IJPR)
PROCESS INNOVATION EXAMPLE

(“Lean” and waste elimination)
Lean in DISSASSEMBLY
Measured Movement velocity
50th percentile

Angular velocity (°/s)

Direct work
Material/tool handling
Casual
Unplaned breaks
Line transport

(Neumann et al., Submitted)
How “Lean” increases employee risk

Car disassembly

(Risk +)

(Recovery -)

(Neumann et al., Submitted)
Enter the Design process
Who Controls Risk? No one & Everyone.
Source of HF problems is throughout Development process.

Outcomes include Performance & Wellbeing.

OHS is isolated.
‘Side Car’ OHS Structure?

Ergonomist

“the irony of ergonomics”
Health focus opens doors, but limits its application

(Theberge & Neumann, 2013, IR/RI)
Production System

Risk Factors

Disorders, Productivity, Quality...

H&S Service

(time lag, delay)

System Design

Product Design

Technical Performance Feedback

Strategies

Technical & Human Performance Feedback

H&S Feedback

Disorders, Productivity, Quality...

(time lag, delay)
People (not tek.) provide sustainable strategic advantage and good work environment helps realize that advantage (RBV View of the firm) (Dul & Neumann, 2009)

95% of studies show win-win effects when HF use in design (Neumann & Dul, 2010, IJOPM)
What have you got to offer Designers?

Safety = performance

Use Goal Hooking Strategies...
Change costs more later

(Miles and Swift, 1998)
Virtual (predictive) HF Metrics

Performance Metrics

Outcome Metrics

Production System

Risk Factors

Outcomes

Strategies

Incomplete Information available

Leading & Process Indicators

Easy To change

More complete Information Available

Lagging & Outcome Indicators

Difficult to Change

(Neumann et al., 2013, ICMR)
Why Engineers Don’t Consider WE

1. Lack Time
2. Lack Knowledge
3. Lack Tools
4. Lack Mandate

TABLE 1. Ranking of Constraints to the Integration of Work Environment (WE) Considerations Into Engineering (n = 441) (Three Marks).

<table>
<thead>
<tr>
<th>Type of constraint</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of time</td>
<td>44</td>
</tr>
<tr>
<td>Lack of work environment</td>
<td>44</td>
</tr>
<tr>
<td>Lack of methods and tools</td>
<td>40</td>
</tr>
<tr>
<td>Customers do not demand</td>
<td>28</td>
</tr>
<tr>
<td>Management does not appreciate</td>
<td>17</td>
</tr>
<tr>
<td>It is difficult to use the automation</td>
<td>17</td>
</tr>
<tr>
<td>Management is not committed</td>
<td>15</td>
</tr>
<tr>
<td>There is no tradition for doing this</td>
<td>13</td>
</tr>
<tr>
<td>It is troublesome</td>
<td>11</td>
</tr>
<tr>
<td>It is not required by the authorities</td>
<td>11</td>
</tr>
<tr>
<td>The safety organization does not ask for it</td>
<td>7</td>
</tr>
<tr>
<td>The subject does not have my interest</td>
<td>6</td>
</tr>
<tr>
<td>Three Marks</td>
<td>5</td>
</tr>
</tbody>
</table>
Niccolo Machiavelli, 1469-1527

- “human beings are wretched creatures, governed only by the law of their own self-interest.“

1. Change is a process
2. Expect resistance
3. Build support

- Innovation makes enemies of all those who prospered under the old regime, and only lukewarm support is forthcoming from those who would prosper under the new.
Think, don’t fight!

Organisational Work

- RESISTANCE?

USE MORE QUANTITATIVE TOOLS

HOOK TO EXISTING GOALS

(Theberge & Neumann, 2010)
Gains with Ergonomics:

- Sickness & abs.
- Productivity
- Lead Time
- Delivery Precision
- Quality
- Flexibility
- more…
Quality as a common interest.

71 Studies, \( \frac{1}{2} \) identify fatigue as a factor

(Kolus et al., submitted)
Fatigue Dose and Quality

Yield vs. Fatigue Dose

$R^2 = 0.2608$

(Dode et al., 2016 IJPR)
Blackberry Case – Embedding HF into Design

(Village et al., 2015, Ergonomics)
Learn to talk to Engineers.

Ergonomics language

- Awkward posture, pinch grips, contact stress
- Risk factor, strain index, working heights

Engineering language

- Cycle time, value-added, waste, imbalances, disturbances
- FMEA, Gemba walk, Hoishin, Kaizen, Value stream mapping
- Key performance indicator, critical to quality, variability

(Villagé et al., 2015, Ergonomics)
Adapt tools to suit the local design process

METHOD + PROCESS!

(Village et al., 2014, IIE-TOEHFS)
Locking the HF-DFA into Process

Engineer: “HF that accommodates KPIs (targets) fits well with DFA - along with cost, scrap etc - this fits in perfectly”
Final Messages

• Risk is EMERGENT, use a systems view
• Risk yields poor performance
• Goal hook: use performance gains to get designer buy-in
• Design teams need training & methods
• OHS is too important to leave to OHS specialists
• Work in design stages for prevention
STOP TALKING ABOUT HERE
STOP TALKING ABOUT HERE
STOP TALKING ABOUT HERE
STOP TALKING ABOUT HERE
Knowledge of Operators Task Demands

1. Project Specifications
   - Data from similar systems
2. Product Design
   - External loads to be exerted
   - Predicted tasks and timing (Some tasks)
3. Logistics System
   - Predicted tasks and timing (further tasks)
   - Predicted Postures
4. Production Strategy
   - Predicted movements and frequencies
   - Measured activity patterns
5. Layouts
6. Work Organisation
7. (Pilot) Operations
   - Knowledge of Operators Task Demands
8. Disposal

Available Data

Existing Assessments
- Anthropometry, Strength Demands
- Add movement frequencies, reach range, and weight for logistics related tasks
- Add further movement frequencies & cycle patterns
- Add postures, static joint moments, static spine load
- Add postures, dynamic joint moments, spine load
- Add EMG, joint kinematics, actual forces exerted

Possible Biomechanical Indicators

(Neumann & Wells, 2006, CRC Press)
Who is involved? Who has knowledge?

Management

Purchasing

Engineering

Nurses

Consultants

Worker

Union Reps

Union Leadership

Ergonomist

Maintenance

Supervisors

Neumann et al. (ACE - 1999) Roles and Relationships...
Roles in Ergonomics

Management

Purchasing

Engineering

Nurses

Union Reps

Worker

Consultants

Supervisors

Ergonomist

Maintenance

Union Leadership

Neumann et al. (ACE - 1999) Roles and Relationships...
Factors most Central in Purchasing Decisions (Mean +/-SD)

1= Not Important at all
7= Very Important

Mean +SD

(Neumann et al., Ergonomics, 2014)

WC and PF not sign. Different, but are from P, U & Q

(Neumann et al., Ergonomics, 2014)
preferences for purchasing goods made under healthy working conditions

Participants claim willing to pay 17.5% more on a $100 product

(Neumann et al., Ergonomics, 2014)
“Ergo” Brand as differentiation strategy

How is Legislation working?
ODAM SYSTEM

Meso (Company) System

Customers / Owners

Demands

Production Strategy

System Design

Production System

Risk Factors

Productivity, Quality, Economy?
QWL / Health?

Society

Company

Individuals

WIDE RANGE OF STAKEHOLDERS not only Managers, Engineers, Operators…
Material Supply Strategy

Heavy Product with poor layout… and manual handling remained a problem

(LBP the single most reported MSD in the shop with >70% incidence)

(Neumann & Medbo, 2010 – Big Box vs. Narrow Bin, IJIE)
Manufacturing Strategies…

1. TQM  Total quality management
2. JIT  Just in time production
3. MC  Manufacturing cells
4. ICBT  Integrated computer based technology
5. CE  Concurrent engineering
6. TPM  Total productive maintenance
7. TBW  Team-based working
8. EMP  Empowerment
9. LC  Learning culture
10. OS  Outsourcing
11. SCP  Supply-chain partnering
12. BPR  Business process reengineering
Arenas of Design – Tools needed

• Organisational Design
  – Organisation of Development
  – Structure, Strategy, Processes, Accountability

• Product/Service Design
  – Defines Assembly Task
  – Defines Market Relationship (and hence demand)

• Production/Operations System Design
  – Technology
  – Work Organisation

© P. Neumann – HFE Lab
What of missing Human Factors aspects?

Virtual (predictive) Metrics

Product Design

System Design

Performance Metrics

Production System

Risk Factors

Outcome Metrics

Outcomes
System Contexts

- Globalization (Netherlands 16th c.)
- ‘Hyper-Competition’ (D’aveni 1994)
- Consumer Power (Klein)
Strategies

Product Design

System Design

Production System

Risk Factors

Outcomes include Performance & Wellbeing

Source of HF problems Is throughout Development process
Ergonomics

'Side Car'

System Design

Product Design

Company Strategies

H&S Service

Production System

Risk Factors

Disorders, Productivity, Quality…

(time lag, delay)

Ergonomics ‘Side Car’

(Neumann & Village, 2012, Ergonomics)
MAP THE DESIGN PROCESS

- Watch out for detail level
- Adapt as needed
- Use participatively to
- Identify Opportunities

Product Design  →  System Design  →  Production System  ↓  Risk Factors

Health, Productivity, Quality…

- **Fixture Development Process**

<table>
<thead>
<tr>
<th>Fixture Design Request</th>
<th>Fixture Design Execution</th>
<th>Fixture Design Validation Prototype</th>
<th>Production Fixture Replication and Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start of the process</strong></td>
<td><strong>Design For Assembly (DFA) review</strong></td>
<td><strong>Prototype Build</strong></td>
<td><strong>Production Tool Replication</strong></td>
</tr>
<tr>
<td><strong>Fixtures RFQ</strong></td>
<td><strong>Design Review</strong></td>
<td><strong>Design refined for Production</strong></td>
<td><strong>Production tool Qualification</strong></td>
</tr>
<tr>
<td><strong>Assembly fixture RFQ award</strong></td>
<td><strong>Design Accepted?</strong></td>
<td><strong>Production fixture build</strong></td>
<td><strong>Lessons Learned</strong></td>
</tr>
<tr>
<td><strong>Fixture design formal request</strong></td>
<td><strong>Design closed-prototype kick off</strong></td>
<td><strong>Tool Verification and Validation</strong></td>
<td><strong>End of the process</strong></td>
</tr>
<tr>
<td><strong>Fixture Design Kickoff meeting</strong></td>
<td><strong>I Release sign off</strong></td>
<td><strong>accepted?</strong></td>
<td><strong>End Process</strong></td>
</tr>
<tr>
<td><strong>Engineering changes</strong></td>
<td></td>
<td><strong>No</strong></td>
<td></td>
</tr>
</tbody>
</table>

Note: HF sign-off required at yellow boxes
BlackBerry Case:
Adapt IE tools to include HF and integrate in design process

(Village et al, IIE TOEHFS, 2014)
How do you estimate worker demand in light assembly?

- Create an easy to use tool that predicts light assembly worker task demands from design criteria.
Flow Simulation Model

Flow Simulation Model (Neumann et al., 2009 IJOPM)
Flow Strategy & Ramp Up with Learning

Learning rate = 75%, Incompessible factor = 25%, C.V. = 10%, No. of products = 1

Cross over range

- Line
- Cell
Organisational level Evaluation
The Human factors Integration Tools (HFIT)

Develop an assessment method to determine HF integration in an organization
- applicable to any organization
- inspiring systems development
- non-prescriptive
DFHF Grounded Theory

1. HFS acclimates and aligns to “fit” within engineering
   1a. HFS acclimates to engineering process, language, and tools
   1b. HFS strategically aligns HF to design and business goals

2. HF becomes a means to improve business performance
   2a. HFS are pulled onto engineering team
   2b. Management hold engineers accountable for HF

3. HF is embedded in design process with enforceable targets
   3a. Engineering tools with targets are adapted for HF
   3b. HF is embedded in engineering process

4. Proposed Outcomes
   Improved worker health & business performance

3. Results, Chapter 7
Design for DISSASSEMBLY - Simulation
A new way of thinking about HF at the Org level

HF Integration Score

- Environmental, Health & Safety
- Training
- Human Resource Management (Hiring and Retention, Employee and Labour Relations and Internal Communications)
- Medical Services & Claims Management
- Marketing/External Communications/Advertising/Retail/Sales
- Finance
- Maintenance
- Tooling
- Construction and Fabrication
- Operations/Supervision
- Scheduling/Operations Planning
- System Engineering / Design
- Product/Service Design
- Logistics (Shipping/Receiving/Material Handling/Warehousing/Storage)
- Organizational Strategy Development (Board of Directors/Senior Management)

Previous Rating
Current Rating
Industrialisation System

Meso (Company) System

Customers / Owners

Demands

Production Strategy

System Design

Production System

Risk Factors

Production System

Company

Individuals

Customers / Owners

Society

WIDE RANGE OF STAKEHOLDERS not only Managers, Engineers, Operators...

Productivity, Quality, Economy?

QWL / Health?