RISK MANAGEMENT
Risk management
Introduction

Risk is uncertain event that, if it occurs, has positive or negative effect on at least one project objective such as scope, time, cost or quality

- Positive risks are opportunities
- Negative risks are threats

Projects always contain risks. If you do not manage project risks, they will derail your projects!

- A risk can have one or several causes, and one or several impacts
- Art of project management is risk management. When done efficiently, risks can be reduced by over 80%
**Risk management**

**Methodology**

**Risk identification**
- Determine which risks might affect project; document their characteristics

**Qualitative risk analysis**
- Prioritize risks for further analysis or action

**Quantitative risk analysis – only if worth it**
- Numerically analyze effect of identified risks on overall project objectives

**Risk response planning**
- Develop options and actions to enhance opportunities and reduce threats

**Risk monitoring and control**
- Track identified risks, monitoring residual risks, identify new risks, execute risk response plans
Main tool for risk analysis is Risk Register

<table>
<thead>
<tr>
<th>ID</th>
<th>Risk</th>
<th>Category</th>
<th>Sub-category</th>
<th>Initial probability</th>
<th>Initial impact</th>
<th>Initial value</th>
<th>Strategy</th>
<th>Owner</th>
<th>Risk response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E.g. specifications unclear</td>
<td>Technical</td>
<td>Requirements</td>
<td>8</td>
<td>8</td>
<td>64</td>
<td>Mitigate</td>
<td></td>
<td>Schedule regular meetings with customer</td>
</tr>
<tr>
<td>2</td>
<td>E.g. € decline, impacting target product margin</td>
<td>External</td>
<td>Market</td>
<td>8</td>
<td>4</td>
<td>32</td>
<td>Avoid</td>
<td></td>
<td>Find suppliers in € zone</td>
</tr>
<tr>
<td>3</td>
<td>E.g. new requirements added without additional budget</td>
<td>Project management</td>
<td>Planning</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>Mitigate</td>
<td></td>
<td>Limit acceptance of new requirements</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Risk management
Methodology

Define rules for risk assessment

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sub-categories</th>
<th>Probability</th>
<th>Impact*</th>
<th>Threats response strategy</th>
<th>Opportunities response strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Requirements, technology, complexity, interfaces, performance, reliability, availability, quality</td>
<td>8 = very high</td>
<td>8 = very high</td>
<td>Avoid</td>
<td>Exploit</td>
</tr>
<tr>
<td></td>
<td>Sub-contractors, suppliers, regulatory, market, customer</td>
<td>4 = high</td>
<td>4 = high</td>
<td>Transfer</td>
<td>Enhance</td>
</tr>
<tr>
<td></td>
<td>Project dependencies, resources, funding, prioritization</td>
<td>2 = moderate</td>
<td>2 = moderate</td>
<td>Mitigate</td>
<td>Share</td>
</tr>
<tr>
<td></td>
<td>Estimating, planning, controlling, communication</td>
<td>1 = low</td>
<td>1 = low</td>
<td>Accept</td>
<td>Accept</td>
</tr>
<tr>
<td>External</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organizational</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Definition of impact scale

<table>
<thead>
<tr>
<th></th>
<th>Low (1)</th>
<th>Moderate (2)</th>
<th>High (4)</th>
<th>Very high (8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COST</td>
<td>&lt; 10% increase</td>
<td>10-20% increase</td>
<td>20-40% increase</td>
<td>&gt; 40% increase</td>
</tr>
<tr>
<td>TIME</td>
<td>&lt; 5% increase</td>
<td>5-10% increase</td>
<td>10-20% increase</td>
<td>&gt; 20% increase</td>
</tr>
<tr>
<td>SCOPE</td>
<td>Minor areas of scope affected</td>
<td>Major areas of scope affected</td>
<td>Scope reduction unacceptable to sponsor</td>
<td>Project end item is effectively useless</td>
</tr>
<tr>
<td>QUALITY</td>
<td>Only very demanding applications affected</td>
<td>Quality reduction requires sponsor approval</td>
<td>Quality reduction unacceptable to sponsor</td>
<td>Project end item is effectively useless</td>
</tr>
</tbody>
</table>
Risk management
Methodology

Risk response strategies for threats

• **Avoid**
  *Eliminate threat* by eliminating cause (e.g. remove work package), isolate project objectives from impact, relax objectives, clarify requirements, improve communication, acquire know-how

• **Mitigate**
  *Reduce probability or impact of threat*, making it smaller risk. Reinforce test plan, choose more reliable supplier, build prototype

• **Transfer**
  *Make another party responsible for risk*, e.g. by outsourcing the work, purchasing insurance

• **Accept**
  *Active acceptance* involve creation of contingency plans and contingency reserves to be implemented if risk occurs. Passive acceptance leaves actions to be determined as needed, if (after) the risk occurs
Risk management Methodology

Risk response strategies for opportunities

- Exploit
  *Exploit opportunity*, e.g. add work or change project to make sure that opportunity occurs, use better resources, improve quality, add functionality, …

- Enhance
  *Increase likelihood* (probability) and / or positive impacts of risk event

- Share
  *Allocate ownership of opportunity to third party* (forming partnership, team, joint venture) that is best able to achieve the opportunity

- Accept
  *Do not implement any action*
Risk management
Methodology

Probability and impact matrix for threats

Risks with highest probability and impact levels must receive focus

<table>
<thead>
<tr>
<th>PROBABILITY</th>
<th>IMPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

These risks require priority actions and aggressive risk response strategies.
These risks require actions and a risk response strategy. Implement risk response if risks move to above category or if time allows.
These risks are not critical. They are documented for periodic review.
Risk management
Methodology

Example of Risk Register for case study, filled out with extended project team

<table>
<thead>
<tr>
<th>ID</th>
<th>Risk</th>
<th>Category</th>
<th>Sub-category</th>
<th>Initial probability</th>
<th>Initial impact</th>
<th>Initial value</th>
<th>Strategy</th>
<th>Owner</th>
<th>Risk response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inability to synchronize mechanical</td>
<td>Technical</td>
<td>Availability</td>
<td>9</td>
<td>2</td>
<td>16</td>
<td>Mitigate</td>
<td>Indus CORES</td>
<td>Buy from well known seller</td>
</tr>
<tr>
<td>2</td>
<td>Displacement of box with image</td>
<td>Technical</td>
<td>Requirements</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>Mitigate</td>
<td>S&amp;A</td>
<td>Tests on PCR machine with camera</td>
</tr>
<tr>
<td>3</td>
<td>Insufficient processing power for</td>
<td>Technical</td>
<td>Performance</td>
<td>2</td>
<td>8</td>
<td>16</td>
<td>Mitigate</td>
<td>R&amp;D GC</td>
<td>Perform test on prototype ASAP</td>
</tr>
<tr>
<td>4</td>
<td>Perturbation caused by dust</td>
<td>External</td>
<td>Reliability</td>
<td>2</td>
<td>8</td>
<td>16</td>
<td>Mitigate</td>
<td>Indus CORES</td>
<td>Today’s solutions are acceptable, analyse and if necessary improve current solutions</td>
</tr>
<tr>
<td>5</td>
<td>Decline in image quality</td>
<td>External</td>
<td>Market</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Accept</td>
<td>Indus CORES</td>
<td>Find suppliers in € zone</td>
</tr>
<tr>
<td>6</td>
<td>Artifacts due to rotation between</td>
<td>Technical</td>
<td>Reliability</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>Accept</td>
<td>S&amp;A</td>
<td>Mitigation solution exists</td>
</tr>
<tr>
<td>7</td>
<td>Life time of processing unit</td>
<td>External</td>
<td>Market</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Accept</td>
<td>Indus CORES</td>
<td>Find suppliers in € zone</td>
</tr>
<tr>
<td>8</td>
<td>Jitter and jam due to data quantity</td>
<td>Technical</td>
<td>Performance</td>
<td>4</td>
<td>8</td>
<td>32</td>
<td>Mitigate</td>
<td>R&amp;D GC</td>
<td>Perform test on prototype ASAP</td>
</tr>
<tr>
<td>9</td>
<td>Precision of detection</td>
<td>Technical</td>
<td>Performance</td>
<td>4</td>
<td>8</td>
<td>32</td>
<td>Mitigate</td>
<td>S&amp;A</td>
<td>Perform customer trials (with broad range of samples)</td>
</tr>
<tr>
<td>10</td>
<td>Technology of industrialisation</td>
<td>Technical</td>
<td>Complexity</td>
<td>4</td>
<td>8</td>
<td>32</td>
<td>Mitigate</td>
<td>Indus CORES</td>
<td>Try assembly setup, and/or investigate alternative solutions</td>
</tr>
<tr>
<td>11</td>
<td>Ending up with a complex HMI</td>
<td>External</td>
<td>Customer</td>
<td>3</td>
<td>8</td>
<td>24</td>
<td>Mitigate</td>
<td>S&amp;A</td>
<td>Involve S&amp;A and field service techs from the start</td>
</tr>
<tr>
<td>12</td>
<td>Not reaching product introduction targets</td>
<td>Project management</td>
<td>Resources</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>Mitigate</td>
<td>Mgmt</td>
<td>Filter requests for current product evolutions</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
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<th>Owner</th>
<th>Risk response</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Dependence on single supplier</td>
<td>External</td>
<td>Suppliers</td>
<td>1</td>
<td>8</td>
<td>8</td>
<td>Accept</td>
<td>Indus CORES</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Desynchronization bw camera and lights</td>
<td>Technical</td>
<td>Reliability</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Accept</td>
<td>R&amp;D QC</td>
<td>Resynchronisation on every top-frame</td>
</tr>
<tr>
<td>11</td>
<td>Fail to provide stable color measurement</td>
<td>Technical</td>
<td>Requirements</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Accept</td>
<td>R&amp;D QC</td>
<td>Backup, sample over more boxes</td>
</tr>
<tr>
<td>18</td>
<td>Precision of register measurement</td>
<td>Technical</td>
<td>Performance</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Mitigate</td>
<td>S&amp;A</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Detection of defect while register tolerance is large</td>
<td>Technical</td>
<td>Reliability</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>Accept</td>
<td>QC</td>
<td>Define a CDC</td>
</tr>
<tr>
<td>33</td>
<td>Availability of Senior Project Manager</td>
<td>Project management</td>
<td>Resources</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Accept</td>
<td>Mgmt</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Modification of reporting tool</td>
<td>External</td>
<td>Estimating</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>Accept</td>
<td>CUBE</td>
<td>CDC to be defined impact on time and budget</td>
</tr>
<tr>
<td>9</td>
<td>Unreliable cooling fan into production plan (lifetime, downtime,...)</td>
<td>Technical</td>
<td>Reliability</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>Mitigate</td>
<td>CUBE</td>
<td>Decision to use cooling</td>
</tr>
<tr>
<td>14</td>
<td>Non real-time OS</td>
<td>Technical</td>
<td>Reliability</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>Accept</td>
<td>R&amp;D QC</td>
<td>Knowledge based on actual systems</td>
</tr>
<tr>
<td>20</td>
<td>Reliability of electronic/LEDs</td>
<td>Technical</td>
<td>Reliability</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>Accept</td>
<td>CUBE</td>
<td>Electronic will be in producer specification</td>
</tr>
<tr>
<td>21</td>
<td>Unreliable white balancing/gain</td>
<td>Technical</td>
<td>Performance</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Accept</td>
<td>S&amp;A</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Impact on resources</td>
<td>Technical</td>
<td>Availability</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Mitigate</td>
<td>WFS</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Incomplete knowledge of customer requirements (process, needs, applicability, uses,...)</td>
<td>External</td>
<td>Customer</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Accept</td>
<td>Mgmt</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bandwidth between state machine and HMI for image transfer</td>
<td>Technical</td>
<td>Performance</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Mitigate</td>
<td>CUBE</td>
<td>Tests to be performed ASAP</td>
</tr>
</tbody>
</table>
Risk management
Methodology

Quantitative risk analysis: numerically analyze effect on overall project objectives of identified risks

Purpose:
- Determine which risk events warrant a response
- Determine overall project risk
- Determine cost and schedule reserves

Expected Monetary Value (EMV) provides overall ranking of risks

\[ \text{EMV} = \text{Probability} \times \text{Impact} \]
EMV can be combined with decision trees

- Example: is it worth to build a prototype for our project?
- Assumptions:
  - Failure if no prototype is built: 70% probability, $450'000 impact
  - Cost of prototype is $200'000
  - Failure even if prototype is built: 35% probability, $120'000 impact

**Prototype:** $200'000

- **Fail:** 35%, $120'000
- **Pass:** no impact

**No prototype:** $0

- **Fail:** 70%, $450'000
- **Pass:** no impact

**EMV**

\[
EMV_{\text{Prototype}} = \$200'000 + 0.35 \times \$120'000 = \$242'000 \\
EMV_{\text{No prototype}} = 0.70 \times \$450'000 = \$315'000
\]

**Conclusion:** better to build a prototype!
Risk management Methodology

Risk response planning: implement actions to reduce risk level and risk mitigation reserves

• **Residual risks**
  - Risks that remain after risk response planning (e.g. accepted risks)
  - Residual risks should be documented and monitored

• **Contingency reserves**
  - Determine amount of contingency time and cost reserves needed to cover *identified risks*. E.g. the project requires 2 months time and $120,000 to accommodate the known risks on the project
  - Contingency reserves are included in cost baseline

• **Management reserves**
  - Account for *unknowns*; items you could not identify in risk management
  - Management reserves are estimated top-down (e.g. 5% of project cost)
Risk management is a key activity in project management

- Risk management should be performed on every medium or large size project
- Risk Register template makes it easy to implement and track risk management
QUALITY MANAGEMENT
Quality management
Introduction

Products can suffer from

• Hardware-related product quality (now) and reliability (over time period) issues, often due to
  • Component failures (choose reliable suppliers during product design!)
  • Poor design choices during product design (e.g. antennagate with iPhone 4 in 2010, impact of thermal and EMC management, …)

• Software-related quality (e.g. bugs, poor usability or learnability) and reliability issues (e.g. memory leaks)

• Other issues (e.g. poor packaging or user documentation)
Quality management

Introduction

Case study showing impact of hardware quality issues

iPhone sales have risen strongly from 1.4 million units in 2007 to **230 million units in 2015**. In July 2016, Apple sold its billionth iPhone
Quality management
Introduction

Statistic below shows failure rates for iPhones, 2 years after item purchase in the United States in 2010, by type of failure. Product malfunction rate is 7.5%
Quality management
Introduction

Assuming 1-year warranty, 230 million units sold in 2015 and 7.5% malfunction rate split equally over 2 years, it means that Apple replaced ~ 8.6 million of these iPhones in 2016.

A 16GB iPhone 6S Plus costs about $236 to build: $231 for Bill of materials (BOM) and $5 for manufacturing costs. Assume that defective devices are replaced for $200 apiece.

**Cost of non-quality for iPhone is ~ $1.7bn annually**, directly impacting company’s margin of $50 bn.

A $100m project that would cut non-quality by 30% would be paid off in 2 months!
Managing quality in projects is more than ensuring good product quality and reliability. It means that

- Project delivers results that are required and have been agreed on, e.g. reaching product performance, product quality and reliability levels, project budget and time-to-market
- Product or service can be used for purpose it was designed for
- Project is managed in adherence with the company's rules & standards

At project beginning
- Check if project could be affected by quality regulations (regulations, norms, standards)
- Define quality procedures, guidelines and methods which apply to project or refer to relevant documentation in company’s quality policy
Agree on quality metrics for each project result, and later use same criteria for project acceptance. Write test plan, defining how product (prototype, pre-series and series) will be tested

- Product reliability: availability (MTTF, MTBF), failure rate
- Environmental sustainability
- Accuracy or operations carried out and repeatability
- Static and dynamic performance
- Rust adhesion and weather resistance
- Mechanical strength
- Resistance to vibrations, temperature, …
Quality management

V-model

V-Model, e.g. used to ensure software or firmware quality, demonstrates relationships between each phase of development lifecycle and corresponding tests to be performed to ensure product quality
Quality management
FMEA

Failure Mode Effects Analysis (FMEA) – “Analyse des modes de défaillance, de leurs effets et de leur criticité (AMDEC)” in French, is preventive quality method used to prevent potential flaws, increasing product reliability level

• Methodology used during development phase of new products

• Identifies flaws and potential causes of failures during design phase, allowing preventive corrective actions to be taken early and avoiding need for costly late design changes

• Anticipate issues early allows to design out failures and design in reliable, safe and customer-pleasing features, increasing customer satisfaction
Methodology to conduct FMEA

• Determine participants
  • Diverse team of people with experience should be involved in order to catch potential failure modes

• Format similar to brainstorming session
  • Identify components, systems, processes and functions that could fail to meet the required level of quality or reliability
  • Do not only describe effects of failure, but also causes
  • For each potential failure mode, determine SEVERITY, OCCURRENCE and DETECTION levels, then prioritize failure modes

• Determine action plan
## Use of FMEA template

### Failure Mode and Effect Analysis

<table>
<thead>
<tr>
<th>Identified Failure Modes</th>
<th>Identified Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No.</strong></td>
<td><strong>Item / Function</strong></td>
</tr>
<tr>
<td>1</td>
<td>Tire inflation</td>
</tr>
<tr>
<td>2</td>
<td>Tire pressure</td>
</tr>
</tbody>
</table>

**Identify failures**

**Identify actions**

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## Failure modes identification

<table>
<thead>
<tr>
<th>ID</th>
<th>Item / Function</th>
<th>Potential failure mode</th>
<th>Potential effects of failure</th>
<th>SEVERITY</th>
<th>Potential cause of failure</th>
<th>OCCURRENCE</th>
<th>Current controls prevention</th>
<th>Current controls detection</th>
<th>DETECTION</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Traction of car</td>
<td>Wrong profile for season</td>
<td>Potential traffic accident due to poor grip</td>
<td>10</td>
<td>Driving on snow without proper equipment</td>
<td>4</td>
<td>Check weather forecast before journey, snow chains available</td>
<td>External temperature</td>
<td>4</td>
<td>160</td>
</tr>
<tr>
<td>4</td>
<td>Support weight of car</td>
<td>Damaged tire</td>
<td>Can lead to puncture and potential traffic</td>
<td>10</td>
<td>Bulge or bubble on the sidewall of a</td>
<td>2</td>
<td>Tire checks before journey</td>
<td>None</td>
<td>7</td>
<td>140</td>
</tr>
</tbody>
</table>

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Quality management
FMEA

Definition of criteria for FMEA analysis

<table>
<thead>
<tr>
<th></th>
<th>Severity</th>
<th>Occurrence</th>
<th>Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor failure, provoking only a short break (&lt; 5 min) and no noticeable degradation</td>
<td>Almost never</td>
<td>Premonitory indication of the failure that the operator can avoid through a preventive action or automatic alarm</td>
</tr>
<tr>
<td>2</td>
<td>Average failure requiring a minor repair and provoking a production stop &lt; 15 min</td>
<td>Once every two years</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Average failure requiring a minor repair and a production stop &lt; 30 min</td>
<td>Once a year</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Critical failure requiring an exchange of defective components and a production stop of &lt; 1 hour</td>
<td>Once every six months</td>
<td>Premonitory indication of the failure, but there is a risk that the operator will not detect it</td>
</tr>
<tr>
<td>5</td>
<td>Critical failure requiring an exchange of defective components and a production stop of &lt; 4 hours</td>
<td>Once every three months</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Very critical failure requiring an exchange of defective components and a production stop of &lt; 8 hours</td>
<td>Once a month</td>
<td>The premonitory indication of the failure is not easily detectable</td>
</tr>
<tr>
<td>7</td>
<td>Very critical failure requiring an exchange of defective components and a production stop of &lt; 24 hours</td>
<td>Once a week</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Catastrophic failure requiring an intervention and a production stop of &lt; 72 hours</td>
<td>Once every eight hours</td>
<td>There is no premonitory indication of the failure, apart the final inspection of the product</td>
</tr>
<tr>
<td>9</td>
<td>Catastrophic failure requiring an intervention and a production stop of &gt; 72 hours</td>
<td>Once every four hours</td>
<td>There is no premonitory indication of the failure before the product is utilized by the customer</td>
</tr>
</tbody>
</table>
Quality management
FMEA

Setting priorities

Risk Priority Number (RPN)
RPN = severity x occurrence x detection

Adjust the FMEA to list failures in descending RPN order
Apply Pareto rule: 80 percent of issues are caused by 20 percent of potential problems. Teams to focus attention on failures with top 20 percent of highest RPN scores.
Quality management

FMEA

Identify corrective actions

- Generate appropriate corrective actions for reducing the occurrence of failure modes at least for improving their detection

<table>
<thead>
<tr>
<th>Identified actions</th>
<th>Owner &amp; completion date</th>
<th>Forecasted effect</th>
<th>Actions taken &amp; effective date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change of tires at the change of the season, vehicle equipped with all year round tires, carry snow chains</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car owner 15.11.2012</td>
<td>3 SEVERITY 2 OCCURRENCE 4 DETECTION 26 RPN</td>
<td>Car equipped with all year round tire and snow chains permanently carried in the trunk</td>
<td></td>
</tr>
<tr>
<td>Carry spare tire and try to inspect after every severe impact</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Quality management
### FMEA

### Example with case study

<table>
<thead>
<tr>
<th>ID</th>
<th>Item / Function</th>
<th>Potential failure mode</th>
<th>Potential effects of failure</th>
<th>SEVERITY</th>
<th>Potential cause / Mechanism of failure</th>
<th>OCCURRENCE</th>
<th>Current controls prevention</th>
<th>Current controls detection</th>
<th>DETECTION</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Assurer intégration machine</td>
<td>Vibrations</td>
<td>Défocalisation</td>
<td>8</td>
<td>Verrouillage défocalisé</td>
<td>1</td>
<td>Audit de qualité</td>
<td>Cible de validation</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>28</td>
<td>Refroidir luminaires et caméra</td>
<td>Pompe chiller</td>
<td>Échauffement des luminaires</td>
<td>9</td>
<td>Thermostat défaillant, pompe bloquée, ...</td>
<td>2</td>
<td>Respect des prescriptions, entretien</td>
<td>Détection hardware de la T des luminaires, et arrêt</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>29</td>
<td>Refroidir luminaires et caméra</td>
<td>Défaut T régulation chiller</td>
<td>Échauffement des luminaires (si T &gt;), condensation (T &lt;), mesure couleur imprécise</td>
<td>8</td>
<td>Thermostat défaillant, mauvais réglage, ...</td>
<td>1</td>
<td>Respect des prescriptions, entretien</td>
<td>Protection du chiller (±/-5°C), Protection software IQ (±/-X°C)</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>30</td>
<td>Refroidir luminaires et caméra</td>
<td>Température de l'air trop élevée</td>
<td>Échauffement des luminaires (si T &gt;), condensation (T &lt;), mesure couleur imprécise</td>
<td>8</td>
<td>Température de l'environnement trop élevée</td>
<td>1</td>
<td>Respect des prescriptions</td>
<td>Protection du chiller (±/-5°C), Protection software IQ (±/-X°C)</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>31</td>
<td>Refroidir luminaires et caméra</td>
<td>Fuite liquide de refroidissement : aigue, corrosion</td>
<td>Échauffement des luminaires (si T &gt;), mesure couleur imprécise</td>
<td>6</td>
<td>Qualité de fluide, entretien non respecté, difficulté de mesure</td>
<td>1</td>
<td>Respect des prescriptions, entretien</td>
<td>Audit de qualité</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>32</td>
<td>Refroidir luminaires et caméra</td>
<td>Fuite liquide de refroidissement : connecteur défectueux</td>
<td>Échauffement des luminaires (si T &gt;), mesure couleur imprécise, dégradation électronique</td>
<td>9</td>
<td>Vissage tube plastique, joint mal serré</td>
<td>1</td>
<td>Respect des conditions de maniement</td>
<td>Visuel</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>33</td>
<td>Refroidir luminaires et caméra</td>
<td>Panne capteur Température (carte électronique)</td>
<td>Échauffement des luminaires (si T &gt;), mesure couleur imprécise</td>
<td>9</td>
<td>Vissage, court-circuit</td>
<td>1</td>
<td>Aucun</td>
<td>Contrôle croisé software (la T ne sera pas dans la bonne plage)</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>34</td>
<td>Refroidir luminaires et caméra</td>
<td>Panne capteur Température (transmission)</td>
<td>Échauffement des luminaires (si T &gt;), condensation (T &lt;), mesure couleur imprécise</td>
<td>9</td>
<td>Court-circuit, cavalier défocalisé, diver ...</td>
<td>1</td>
<td>Aucun</td>
<td>&quot;Watchdog&quot; hardware</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>
Project economics

New products are launched to generate net profit margin for company. Project financial viability must be demonstrated at project launch

- During project development company will only incur cost (=cash outflows). After product launch company will have residual project cost, and revenues will be generated (=cash inflows). After project closing company will incur only revenues

- When considering if investment shall be made in a project, company must consider the cost to borrow money, so-called weighted average cost of capital (WACC)
Project economics
Methodology

Step 1: estimate overall project cost over time

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
<th>kCHF</th>
<th>%</th>
<th>Costs until Gate 7 splitted per year</th>
</tr>
</thead>
</table>
| R&D Mechanical                          | 500   | 500  | 28% | 0%  
| R&D Electrical                          | 300   | 300  | 17% |  
| R&D Validation                          | 100   | 100  | 6%  |  
| R&D Pre-serial and Updates              | 30    | 30   | 2%  |  
| R&D Project Management and Support      | 100   | 100  | 6%  |  
| **Subtotal R&D costs**                  | 1030  | 5%   | 40% | 40% | 15% | 0%  |
| SPL Industrialisation                   | 150   | 150  | 8%  |  
| SPL Project Management and Support      | 50    | 50   | 3%  |  
| **Subtotal SPL costs**                  | 200   | 5%   | 20% | 60% | 15% | 0%  |
| M/S Open House costs                    | 50    | 50   | 3%  |  
| M/S Tools, pictures, videos, brochures, advert. | 50 | 50 | 3% |  
| M/S Boxes for open house, tests and demos | 20   | 20   | 1%  |  
| M/S Project Management and Support      | 30    | 30   | 2%  |  
| **Subtotal Marketing and Sales costs**  | 150   | 5%   | 5%  | 50% | 50% | 0%  |
| Services Field Interventions            | 100   | 100  | 6%  |  
| Services Technician Training            | 20    | 20   | 1%  |  
| Services Warranty                       | 60    | 60   | 4%  |  
| Services Project Management and Support | 20   | 20   | 1%  |  
| **Subtotal Services costs**             | 220   | 5%   | 0%  | 50% | 50% | 0%  |
| Risk reserve                            | 200   | 200  | 11% |  
| **Total costs Base case**               | 1800  | 100% |  
| Total costs Worst case                  | 1080  | 110% |  
| Total costs Best case                   | 1620  | 50%  |
Step 2: estimate margin obtained from selling the product

<table>
<thead>
<tr>
<th>Target Production Costs</th>
<th>kCHF</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>End User Price (EUP)</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Gross Margin</td>
<td>90</td>
<td>30%</td>
</tr>
<tr>
<td>Training / Instruction</td>
<td>5</td>
<td>2%</td>
</tr>
<tr>
<td>Others</td>
<td>5</td>
<td>2%</td>
</tr>
<tr>
<td>Cost of Sales (COS)</td>
<td></td>
<td>67%</td>
</tr>
<tr>
<td>Engineering / Specialty</td>
<td>25</td>
<td>8%</td>
</tr>
<tr>
<td>Transports / Insurance</td>
<td>10</td>
<td>3%</td>
</tr>
<tr>
<td>Installation</td>
<td>10</td>
<td>3%</td>
</tr>
<tr>
<td>Cost of Goods Sold (COGS)</td>
<td>155</td>
<td>52%</td>
</tr>
<tr>
<td>Packaging</td>
<td>5</td>
<td>2%</td>
</tr>
<tr>
<td>Machine Production Costs</td>
<td>150</td>
<td>50%</td>
</tr>
</tbody>
</table>
Project economics
Methodology

Step 3: estimate sales forecast over time

**SALES FORECAST**

Worst Case represents **80%** of Base Case GM Forecast
Best Case represents **120%** of Base Case GM Forecast

<table>
<thead>
<tr>
<th>Additional Sales Forecast (Base Case)</th>
<th>EUP</th>
<th>GM/Unit</th>
<th>Current Sales/Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>New product (no cannibalization)</td>
<td>300</td>
<td>90</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New product (no cannibalization)</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>15</td>
<td>25</td>
<td>20</td>
<td>15</td>
</tr>
</tbody>
</table>

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Calculate project metrics: Net Present Value and Payback time

**PROJECT PROFITABILITY**

- **Gate 2**: 01.09.2016
- **Gate 3 estimated**: 01.12.2016
- **Gate 6 (start serial production)**: 01.09.2018
- **First Ex-Works machine**: 01.11.2018
- **Gate 7 (end project)**: 01.06.2019
- **WACC**: 10.00%

**Payback date (base case)**: 27.01.2020

- **Project costs (base case)**: kCHF 1'800
- **Additional annual TO (base case)**: kCHF 7'500
- **Additional annual GM (base case)**: kCHF 2'250

**Net Present Value (NPV) 5 years from Gate 3**

- **Worst**: kCHF 1'098
- **Base**: kCHF 1'893
- **Best**: kCHF 2'689

**Payback in years since Gate 3**

- **Worst**: 3.5
- **Base**: 3.2
- **Best**: 2.8
**Project economics**

**Net Present Value (NPV)** is used in capital budgeting to analyze the profitability of projects. It represents difference between present value of cash inflows and the present value of cash outflows. A positive NPV indicates that projected earnings generated by project exceeds anticipated costs. **Investment with positive NPV is profitable**, with negative NPV will result in net loss.

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenses</th>
<th>Revenues</th>
<th>Annual cash flow</th>
<th>Discounted cash flow (NPV) with 10% WACC</th>
<th>Cumulative NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>2'000</td>
<td>0</td>
<td>-2'000</td>
<td>-2'000</td>
<td>-2'000</td>
</tr>
<tr>
<td>2018</td>
<td>250</td>
<td>100</td>
<td>-150</td>
<td>-136</td>
<td>-2’136</td>
</tr>
<tr>
<td>2019</td>
<td>100</td>
<td>500</td>
<td>400</td>
<td>331</td>
<td>-1’806</td>
</tr>
<tr>
<td>2020</td>
<td>100</td>
<td>1000</td>
<td>900</td>
<td>676</td>
<td>-1’130</td>
</tr>
<tr>
<td>2021</td>
<td>100</td>
<td>1500</td>
<td>1400</td>
<td>956</td>
<td>-173</td>
</tr>
<tr>
<td>2022</td>
<td>100</td>
<td>2000</td>
<td>1900</td>
<td>1180</td>
<td>1’006</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2’650</td>
<td>5’100</td>
<td>2’450</td>
<td><strong>1006</strong></td>
<td></td>
</tr>
</tbody>
</table>
Other indicators to determine if project will yield positive financial benefits

• **Internal Return Rate (IRR) in %** is discount rate that makes project have a zero NPV. It computes interest rate at which future costs equal future revenues. The higher the IRR the better!

• **Return on Investment (ROI) in %** measures financial gains of project in relation to its cost. \[ \text{ROI} = \left( \frac{\text{project’s financial gain} - \text{project cost}}{\text{project cost}} \right) \times 100 \]

• **Payback period in years** refers to period of time required to recoup the investment in project, to reach the break-even point. E.g. a $1000 investment made at start of year 1 which returned $500 at end of year 1 and year 2, respectively, would have a two-year payback period (neglecting WACC)
Once a financial model is available, it can be useful to perform a sensitivity analysis to identify major drivers behind cumulated profit and to drive decisions during project, e.g.

- Trade development cost for time
- Increase development cost to further reduce product cost
REDUCING WASTE IN PRODUCT DEVELOPMENT
Waste in product development

Lean principles applied in variety of manufacturing processes, but applications in product development are slower to come

Estimated that 20-40% of product development effort is pure waste, and that 60-80% of tasks are idle at any given time

Lean principles offer opportunities to improve product development value stream

This chapter focusses on waste identification in product development processes
Waste in product development
Strategic waste

- **Overproduction**
  - Developing products that are not currently needed / not needed at all
  - Having too many products or options
  - Having too many development projects (lack of focus)
  - Overlap of strategic and non-strategic projects competing for limited resources
- **Selecting wrong projects**, not focussing on projects with highest ROI
- **Projects with poor risk identification and management** during development
- **Technologies acquired but later not used** (e.g. Quadline, Braille reading)
- **Poor make-vs-buy decisions**
- **Poor understanding of long-term customer needs**
Waste in product development
Organizational waste

• Poor organization structure
  • Poor development process
  • Inefficient gates validation process
  • Project objectives not clear
  • Roles and responsibilities not clear / not understood
  • Lack of cooperation between departments or teams (silos)
  • Insufficient responsibility of project team
  • Poor tracking of project planning and cost, and product cost
  • Poor training of team members
  • Inappropriate selection of project team members
  • Team spread over different locations
  • Not taking advantage of lessons learned
  • Projects started without sufficient resources
Waste in product development
Organizational waste

• Waste of human potential
  • Strengths or skills of team members not used properly
  • Underutilizing people’s knowledge and creativity
  • Lack of interdisciplinary coverage among team members
  • Lack of continuity during projects
  • Too much administration

• Inappropriate processes and tools
  • Inadequate product development processes
  • Poor understanding of development process
  • Changing processes
  • Use of inadequate tools and methodologies (e.g. using 2D instead of 3D)
  • Use of tools and methodologies that are not necessary
  • Insufficient IT resources
Waste in product development
Operational waste

- **Waiting.** No value is added while people wait for product to process or product waits for people or machines.

  - People waiting for data, answers, specifications, requirements, test results, approvals, validations, decisions, project launch, design reviews, hand offs, task dependencies, prototypes
  - Information waiting for people, created too early
  - Projects / tasks waiting for resource availability
  - Delivery postponed (components, information, test results)
  - Unbalanced workflow within the team
Waste in product development
Operational waste

• **Transport**
  • Team members traveling between sites
  • Inefficient communication
  • Misunderstandings and non-conformities
  • Lack of process standardization
  • Lack of standardized components utilization
  • Lack of prioritization
  • Lack of standardized and compatible data formats
  • Poor information systems requiring manual transfer and conversion issues
  • Poor interface controls and database transfers between sites / departments
  • Transfer of products / processes from one department to another
  • Multitasking, tasks being started and paused
Waste in product development
Operational waste

• **Inventory** is collection of unprocessed documents, data objects, and transactions queued-up between people and processes

  • Unnecessary details and information (e.g. on drawings)
  • Incomplete content
  • Poor management of configuration
  • Poor codification of components
  • Too much data stored, making it hard to find relevant information on server
  • Unnecessary test equipment or prototypes
  • Queues on critical path
  • Projects waiting, people waiting, resource overcapacity
Waste in product development
Operational waste

• **Movement.** Excess movement by people or equipment consumes time and resources without producing value

  - Information pushed to wrong people
  - Unnecessary manual interventions because of poor system connectivity
  - Too many data interfaces
  - Delocalized development sites
  - Lack of direct access to information or resources
  - Software efficiency: number of mouse clicks, of routines, of transactions
  - Searching for drawings and other information on remote servers
Waste in product development
Operational waste

- **Excess processing.** Doing more than what is necessary to generate satisfactory value as defined by the customer
  - Unnecessary tasks, development activities, sequential treatment of tasks
  - Work not done in proper sequence because of poor integration
  - Change requests due to changing priorities, product or process requirements
  - Over-specifications, changing product requirements
  - Over-designed or over-engineered product
  - Too many design iterations
  - Work with wrong or incomplete information
  - Information passed on too early or too late
  - Data acquired but not used
  - Tolerances too tight
  - Too many details or unnecessary information
  - Redundant tasks or development (insufficient design reuse)
  - Poor reuse of knowledge
Waste in product development
Operational waste

• **Defects** are the result of executed processes that did not produce value
  • Improper information on drawings, missing views, undocumented software code
  • Rework of product
  • Incomplete information or errors in BOM and other R&D documents
  • Lack of understanding of product requirements
  • Errors during parts procurement, prototype assembly, installation
  • Product flaws resulting in missing specifications or customer expectations
  • Errors in configuration management
  • Errors in planification
  • Poor selection of suppliers
  • Use of immature or risky technologies
  • Use of inappropriate tools
  • Errors in communication and data
  • Errors in tests and reports
Waste in product development

8 lean product development questions

1. **Can we eliminate?** Remove unnecessary features
2. **Can we reduce?** E.g. use inflating device instead of spare tire
3. **Can we substitute?** E.g. tablets are substituting newspapers
4. **Can we separate?** Separate and combine work into smaller chunks that are easier to outsource, manufacture, maintain
5. **Can we integrate?** Combine to create new solutions (e.g. waffle and ice cream)
6. **Can we re-use?** Avoid cost and risk of development, e.g. using platforming
7. **Can we standardize?** One solution across entire business model chain, modular design
8. **Can we increase?** Add distinctive features to have competitive advantage
Conclusion

Managing projects is a difficult exercise, with many constraints that have to be taken care of. Managing new product developments, especially when the innovation content is high, is a perilous exercise!

To succeed in your future endeavors, a necessary but not sufficient prerequisite is to master the basics of project management methodology!