29th Annual INCOSE
international symposium

Orlando, FL, USA
July 20 - 25, 2019

University of
South-Eastern Norway

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A practical study on how proactive quality approach can improve system development process to ensure system-effectiveness and -performance

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Agenda

- Industry context – the company
- Identified problem
- Research question
- Background - Literature
- Research Method
- Current system development process in the company
- Case study: Project Lierås
- Revised system development process in the company
- Revised case study: Project Lierås
- Answering research question
- Discussion of findings

Industry context – wastewater-treatment

- Module decentralized wastewater-treatment systems (MDEWATS) are gaining interest
  - Compared to centralized systems
    - Serve small groups of individuals and stakeholders
    - Less up-front investment and maintenance
    - Possibility to provide a “fit for purpose” system with small alternations in design
    - Effective towards scaling operation to stakeholder needs
- The Company
  - Constructs and operates these MDEWATS
  - Company founded in 2011
  - Delivered in 2017 first type of these systems
  - 3-month time-to-market

http://www.nordiskvannteknikk.no/produkt/mobile-anlegg/

Identified problems

- Employees have some improvement potential on their quality focus
- Company have clear improvement potential on systems engineering related activities
- Issues with system-effectiveness and -performance

Research question

- How can a proactive quality approach aid the company in improving their system development process, and ensuring that future wastewater-treatment systems are more effective and have a higher performance compared to today situation?
  - How can the quality tools allow the company to improve their development process on systems engineering related activities?
  - How can proactive quality tools aid in ensuring quality assurance for the company?
  - How can quality assurance allow for more effective and higher performance of future wastewater-treatment systems created by the company?

Background - Literature

- Proactive approach vs Reactive approach (Pyzdek and Keller, 2014)
  - In proactive, focus on preventing non-conformances before they occur
  - In reactive, focus on dealing with non-conformances after they have occurred
- Iceberg principle (Campanella, 1990)
  - True costs of non-conformances are often higher than the direct costs of non-conformances to quality
    - Intangible/hidden costs such as additional engineering time (rework), delivery problems, loss of reputation for the organization, etc.
- Other studies
  - True costs of non-conformances are 3 to 10 times higher than the direct costs (Basak et al., 2015, Pascual and Kumar, 2016)
  - Costs to fix faults in a system increases in an exponential fashion throughout the system life cycle (Stecklein et al., 2004, Walden et al., 2015)
- Cost of errors identified through a reactive manner is higher than prevention through a proactive manner

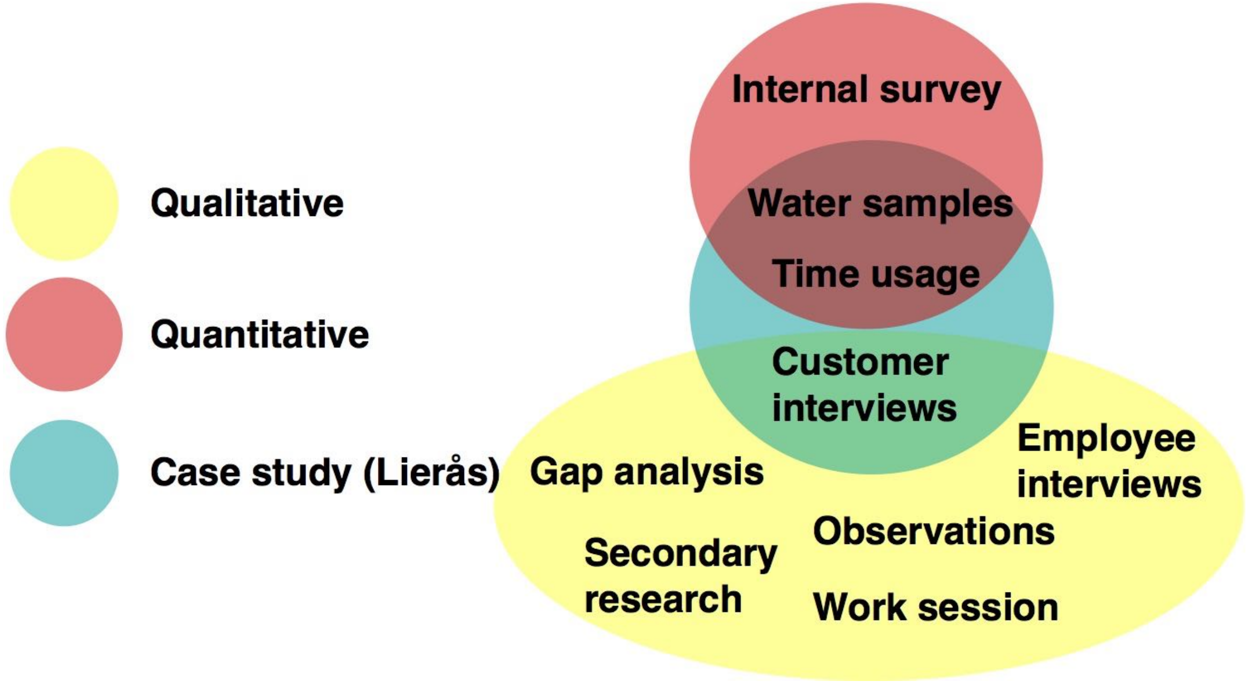
- Quality assurance (NATO Communications and Information Systems School, 2015)
  - “Fit for purpose” system created “right first time”

Background - Literature

- System effectiveness (Roedler and Jones, 2005)
  - Customers viewpoint
  - System validation against customer requirements
- Systems engineering related activities (Sofer, 2017)
  - Activities in scope of systems engineer in addition to system-management and –implementation
  - Critical to *ensure* a successful system realization
  - Successful system is one that satisfy customer needs
- System performance (Roedler and Jones, 2005)
  - Suppliers viewpoint
  - System verification against system requirements
- Technical performance parameters (Roedler and Jones, 2005)
  - Derived from system performance
    - Will reduce system performance if not met
    - Operational requirements (mean time to failure, fault tolerance etc.)

Research method

- Mixed-method gap analysis (Clark and Ivankova, 2016)
  - Emphasizes on use of one primary research method
  - Additional methods to support findings in primary method

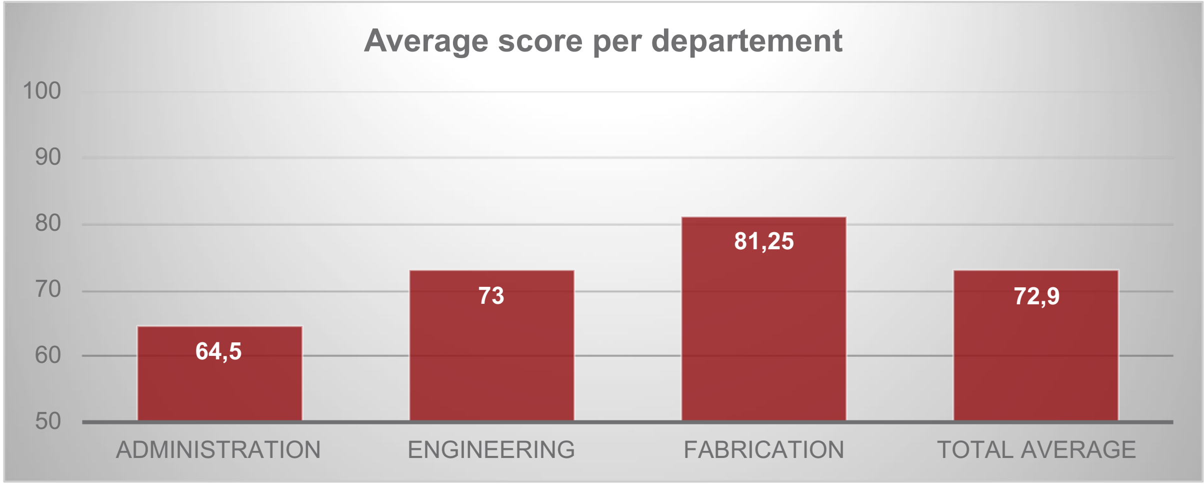


Current system development process

- How was focus on quality in the company prior to our research?
- Survey developed by Hodgetts (1998)
  - We used it to reveal if there were improvement potential on the quality focus in the company
- 71, 4% of the employees answered the survey
- Total average score of 72,9 %
  - Per Hodgetts (1998) interpretation key the company

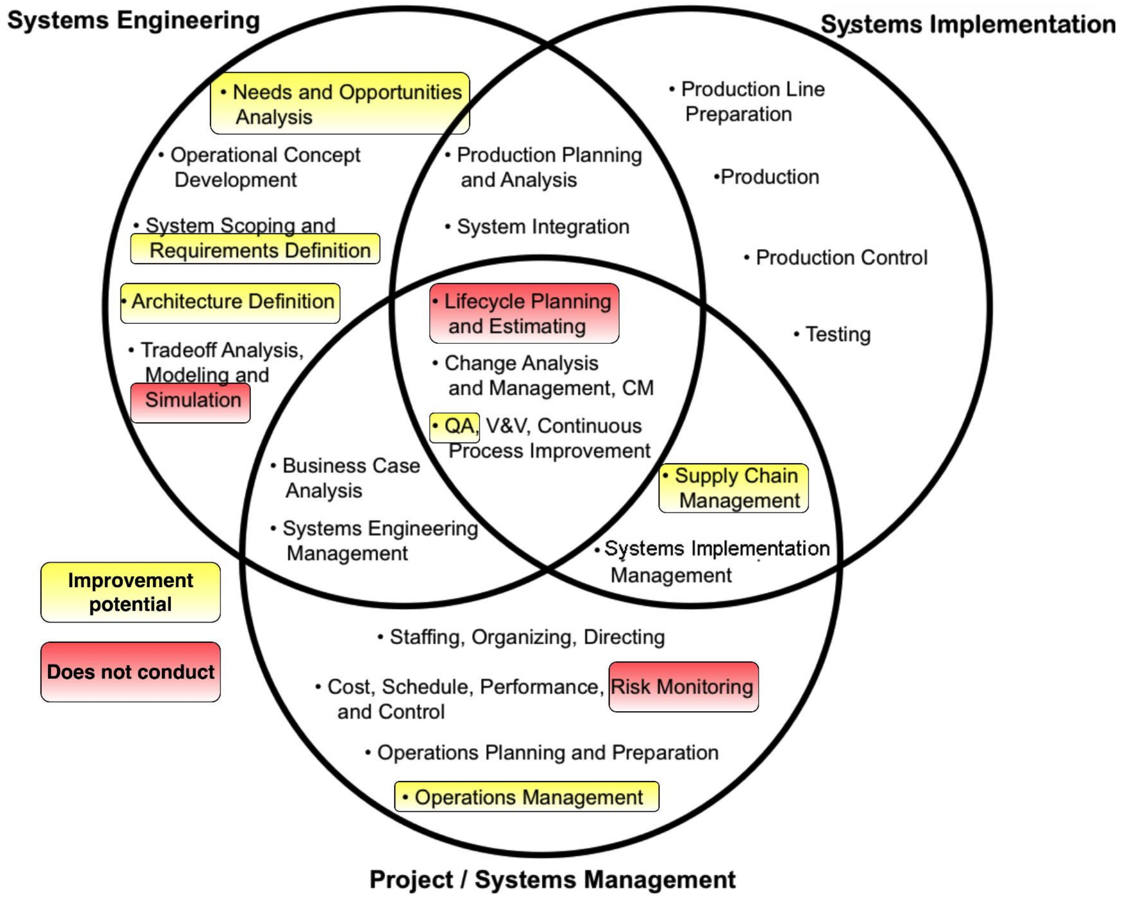
has not fully accepted some of the truths about quality

- Lowest scores from survey
  - “Perfection should be actively pursued”
  - “Large and small gains are necessary to improve quality”



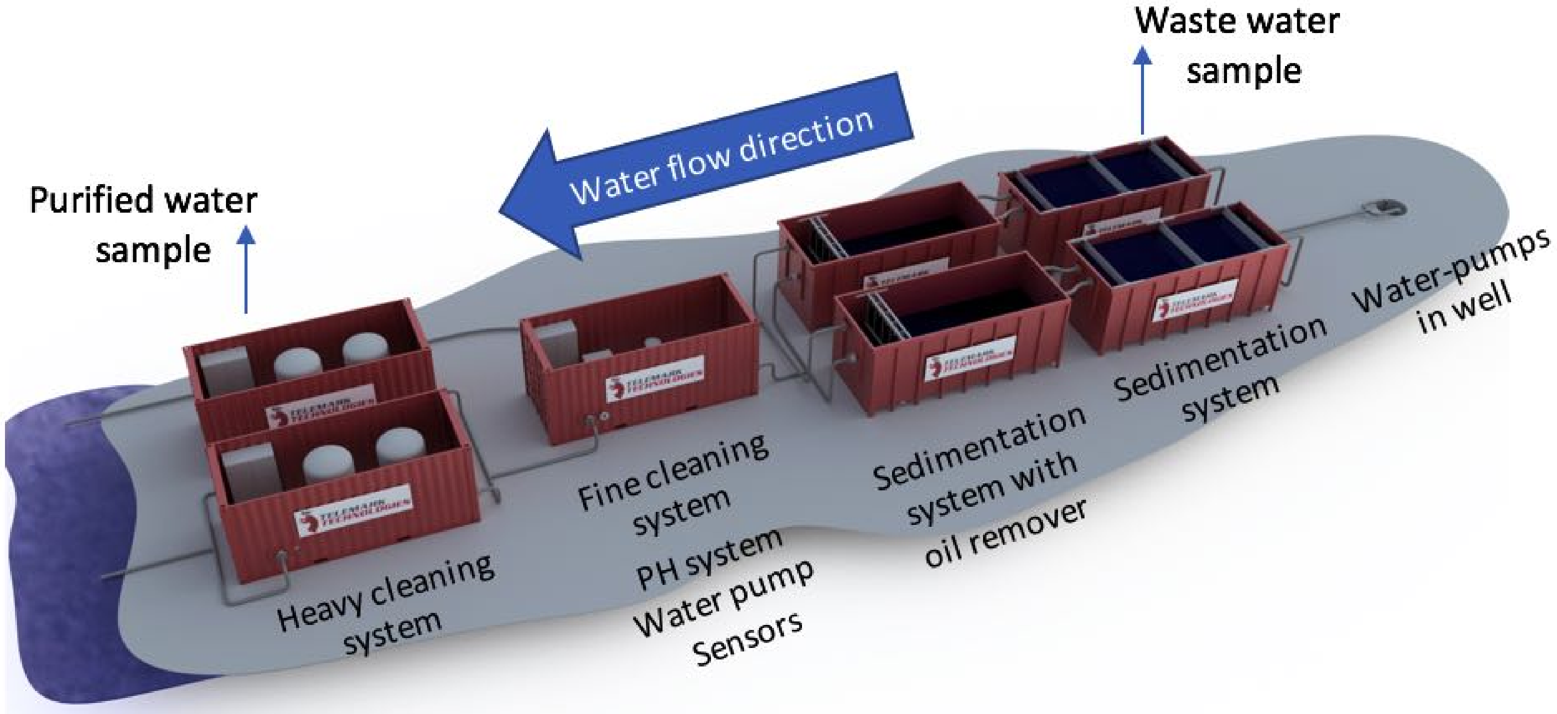
Current system development process

- Systems engineering related activities
  - Some of the following that TT does not conduct
    - Risk Monitoring
  - Some of the following that TT has improvement potential
    - Needs and Opportunities Analysis
    - Supply Chain Management
    - Requirements Definition
    - Quality Assurance (QA)



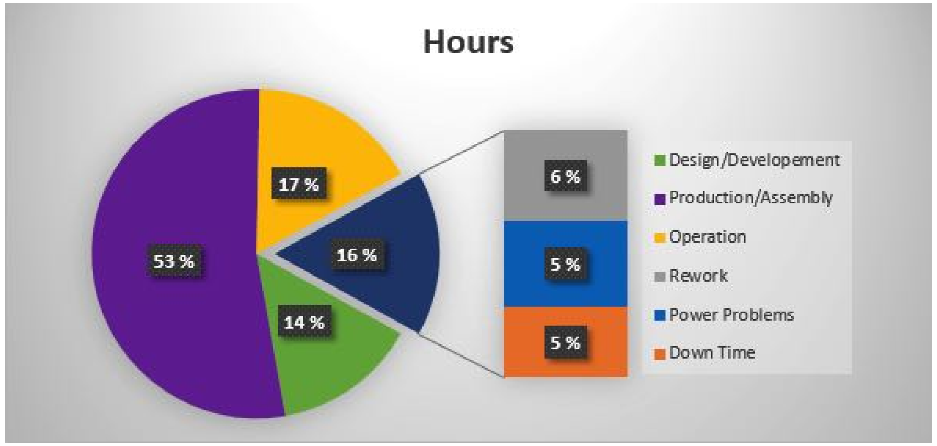
Case study Lierås

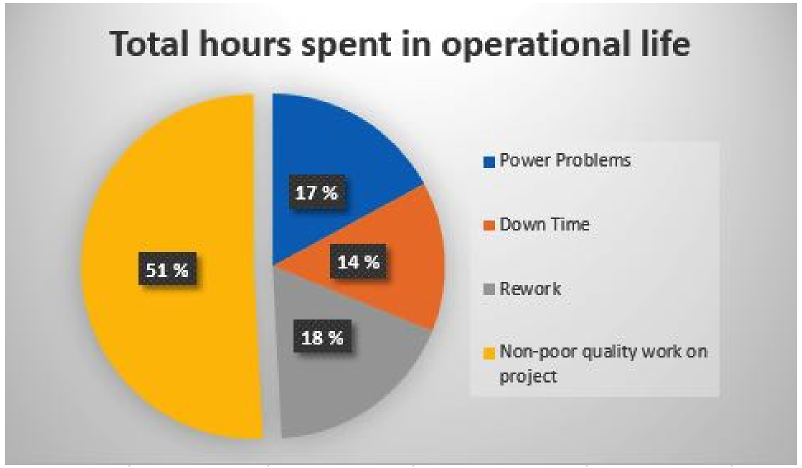
- Module-based containers
  - Each container is responsible for a specific cleaning function
  - Pipes connects containers to each other
- Additional sub-systems
  - Monitoring system
  - External power system
  - Power distribution system
  - Sampling system



Case study Lierås

- Time sheets on hours used from start to current date
  - 22nd of January 2017 to 20th of April 2018.
- Two reasons for data analysis
  - Understand if company lives by the “fit for purpose” and “right first time” principle of quality assurance
  - Identify in what system elements non-conformances occurred
    - ***Piping system***: Changing frozen pipes and leaking valves
    - ***External power system***: Empty fuel tank on the generator
    - ***Power distribution system***: Power failure
    - ***Monitoring system***: Fixing surveillance camera and changing out gauges



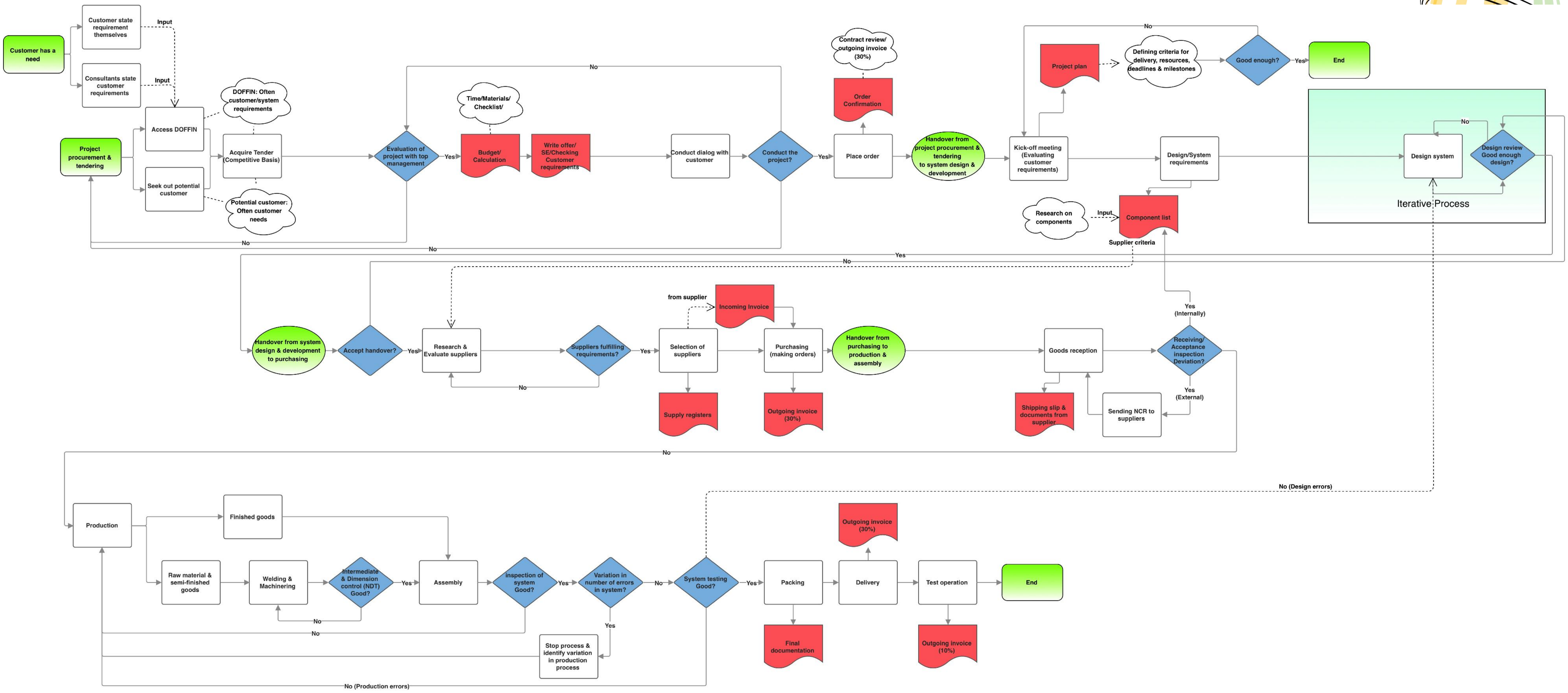


Case study Lierås

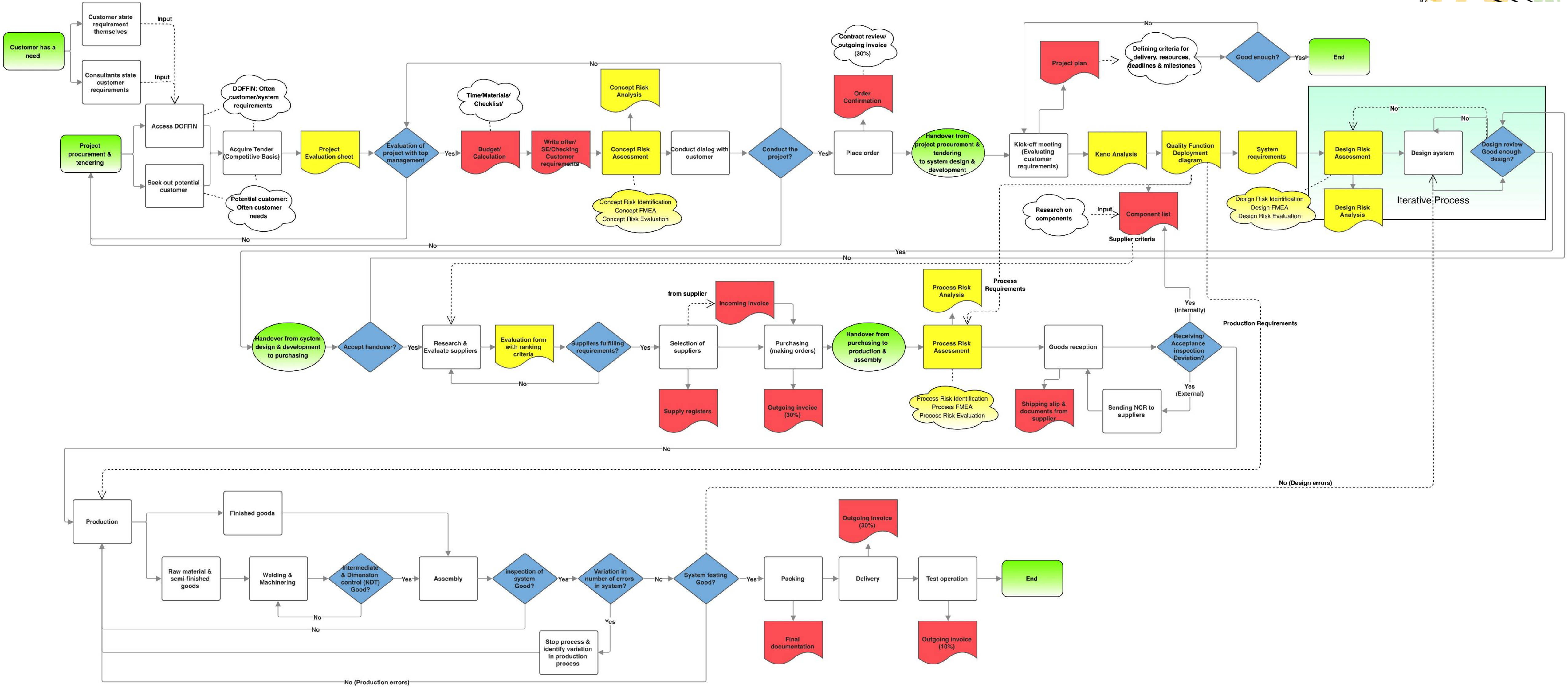
- System effectiveness
  - Purifies substances to under required levels from discharge permit
  - Issues regarding requirement about continuous operation
- System performance
  - Substances in purified water have a higher measured value compared to wastewater
  - System elements have failed in operational life

Revised system development process

- Proposed proactive quality tools that improve performance of system development process
  - Kano analysis
  - Project evaluation sheet
  - Quality Function Deployment
  - Concept-, Design- and Process-risk assessment
  - Supplier evaluation criteria



Customer has a need
Customer state requirement themselves
Consultants state customer requirements
Input
Input
Project procurement & tendering
Access DOFFIN
Seek out potential customer
DOFFIN: Often customer/system requirements
Acquire Tender (Competitive Basis)
Potential customer: Often customer needs
Evaluation of project with top management
Yes
No
Time/Materials/ Checklist/
Budget/ Calculation
Write offer/ SE/Checking Customer requirements
Conduct dialog with customer
Conduct the project?
Yes
No
Contract review/ outgoing invoice (30%)
Order Confirmation
Place order
Handover from project procurement & tendering to system design & development
Kick-off meeting (Evaluating customer requirements)
Project plan
Defining criteria for delivery, resources, deadlines & milestones
Good enough?
Yes
No
End
Design/System requirements
Design system
Design review Good enough design?
No
Iterative Process
Research on components
Input
Component list
Supplier criteria
Yes
No
Handover from system design & development to purchasing
Accept handover?
Yes
Research & Evaluate suppliers
Suppliers fulfilling requirements?
Yes
No
from supplier
Incoming Invoice
Selection of suppliers
Purchasing (making orders)
Supply registers
Outgoing invoice (30%)
Handover from purchasing to production & assembly
Goods reception
Shipping slip & documents from supplier
Sending NCR to suppliers
Receiving/ Acceptance inspection Deviation?
Yes (Internally)
Yes (External)
No
No (Design errors)
Production
Finished goods
Raw material & semi-finished goods
Welding & Machinering
Intermediate & Dimension control (NDT) Good?
Yes
No
Assembly
inspection of system Good?
Yes
No
Variation in number of errors in system?
No
Yes
Stop process & identify variation in production process
System testing Good?
Yes
No (Production errors)
Packing
Final documentation
Outgoing invoice (30%)
Delivery
Test operation
Outgoing invoice (10%)
End



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Project Evaluation sheet
Evaluation of project with top management
Yes
No
No
Time/Materials/ Checklist/
Budget/ Calculation
Write offer/ SE/Checking Customer requirements
Concept Risk Analysis
Concept Risk Assessment
Concept Risk Identification
Concept FMEA
Concept Risk Evaluation
Conduct dialog with customer
Conduct the project?
Yes
No
Contract review/ outgoing invoice (30%)
Order Confirmation
Place order
Handover from project procurement & tendering to system design & development
Kick-off meeting (Evaluating customer requirements)
Project plan
Defining criteria for delivery, resources, deadlines & milestones
Good enough?
Yes
No
End
Kano Analysis
Quality Function Deployment diagram
System requirements
Design Risk Assessment
Design system
Design review Good enough design?
No
No
Design Risk Analysis
Design Risk Identification
Design FMEA
Design Risk Evaluation
Iterative Process
Research on components
Input
Component list
Supplier criteria
Yes
No
Handover from system design & development to purchasing
Accept handover?
Yes
Research & Evaluate suppliers
Evaluation form with ranking criteria
Suppliers fulfilling requirements?
No
Yes
Selection of suppliers
from supplier
Incoming Invoice
Supply registers
Purchasing (making orders)
Outgoing invoice (30%)
Handover from purchasing to production & assembly
Process Risk Analysis
Process Requirements
Process Risk Assessment
Process Risk Identification
Process FMEA
Process Risk Evaluation
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No (Production errors)
Packing
Final documentation
Delivery
Outgoing invoice (30%)
Test operation
Outgoing invoice (10%)
End

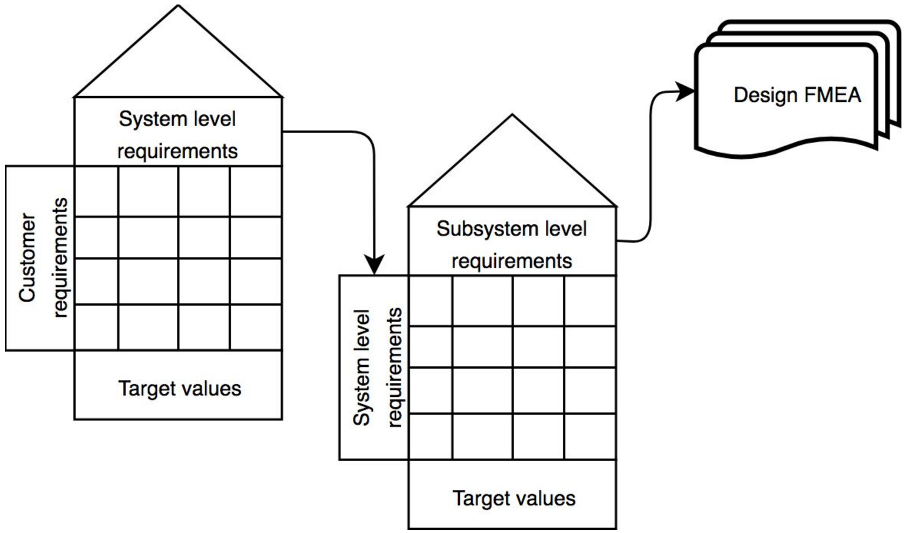
Which tools to implement?

- Employees resistant to change (Rosenberg and Mosca, 2011)
  - Fear of the unknown, disruption of routine and increased workloads etc.
- Design of the system considered as complete after *project procurement & tendering phase*, and *system design & development phase*
- Focus early in system development process
  - Due to exponential increase of fault costs
- Familiarity in company for tools in the mentioned phases
  - Project evaluation sheet
  - Quality Function Deployment
  - Design risk assessment
- Disregard project evaluation sheet in this case study
  - No comparative basis to other projects
  - Should be implemented in future

Quality tool	Intended department involved	Familiarity % respondents	Purpose
Project evaluation sheet (matrix-diagram)	Administration & Engineering	4 of 6 = 66,7 %	Project feasibility
Kano analysis	Engineering	1 of 2 = 50 %	Fit for purpose
Quality Function Deployment	All	6 of 11 = 54,5 %	Fit for purpose
Concept-, Design- and Process-risk assessment	All	7 of 11 = 63,6 %	Right first time
Supplier evaluation criteria (matrix-diagram)	Administration	4 of 4 = 100 %	Fit for purpose at lower cost

Case study Lierås: Quality Function Deployment

- First level
  - Customer requirements weighted with importance which was based on customer interviews with Bane Nor
  - Customer requirements translated to system level requirements
- Second level
  - System level requirements translated to subsystem level requirements
- Subsystems that received highest importance score on second level affect customer requirements most
  - Piping system
  - Monitoring system
  - Power system
  - Sampling system
  - Water pumping system
- These subsystems were carried over to a design risk assessment



Case study Lierås: Design risk assessment

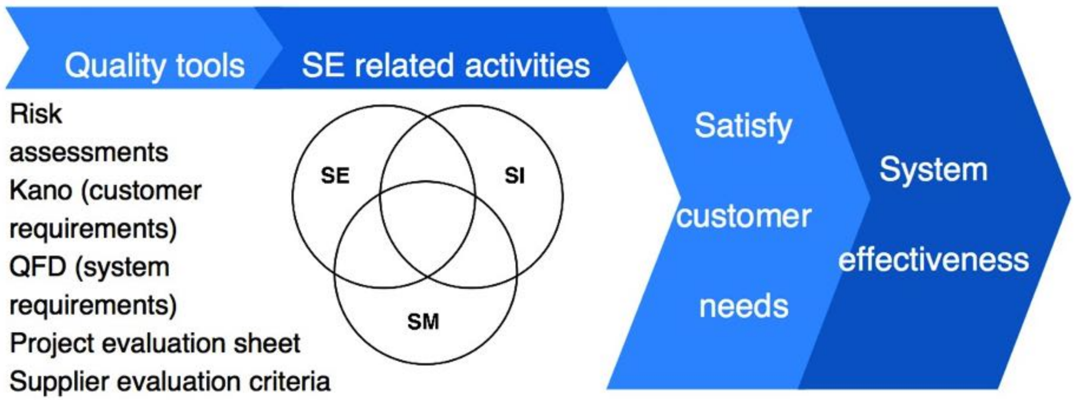
- The assessment targets some of the non-conformances identified from the time sheets
  - Piping system due to leaking valve
  - Power problems due to empty fuel tank
  - Monitoring system due to fixing surveillance

  and gauges
- Risk priority number (RPN) score reflect observations on how company have designed the current system
  - Probability for failure to occur
  - Consequences of failure
  - Detectability of these failures
- RPN score evaluated against the ALARP principle
  - All sub-systems except the monitoring system had failure modes that should be mitigated to reduce the RPN
- Reduction in the RPN could have reduced the risk of non-conformance materializing to the most important customer requirements from Quality Function Deployment

Item/ Function	Potential Failure Mode(s)	Potential Consequence(s) of Failure	C[1]	Potential Cause(s)/ of Failure	P[2]	Current Design Controls	D[3]	RPN	Recommended Action(s)	Action Results			
										New C	New P	New D	New RPN
Monitoring system	Disrupted surveillance	Loss of data integrity/quality	6	Software malfunction, unreliable gauges	3	Warning system, Online surveillance	1	18	None	6	3	1	18
Sampling system	Biased data	Loss of data integrity/quality	8	Manual handling	6	Sampling procedures	6	288	Automation in procedure or training of personnel	5	4	3	60
Water pumping system	Disrupted water flow	Loss of continuous operation, reduced plant capacity, operability	7	Blocked inlet (by large particles), to little pull from pumps	4	Inspections	6	168	Sensor or camera for surveillance of water flow and building fence before inlet	4	3	2	24
Piping system	Leaking valve	Contamination, Poor cleaning, reduced capacity	7	In-correct dimensions	6	Inspections	3	126	Simulations, Factory sub-system testing, 2 stage valve system	3	3	2	18
Power system	Loss of power	System down-time	8	Empty fuel	5	Cameras monitoring power distribution, inspections	5	200	Online surveillance of fuel level	8	4	2	64

How is new system development process, system-effectiveness and –performance improved?

- Quality tools correct misunderstood focus about quality that employees had in the organization
  - Each tool ensure that perfection is pursued actively
  - Each tool aid in small gains to improve quality
- Quality tools improve on some of those systems engineering (SE) related activities where the company have improvement potential
- Improvement in SE related activities should improve system effectiveness
  - SE related activities *ensure* a successful system realization
  - Successful system is one that satisfies customer needs
  - System effectiveness is a measure of customer satisfaction
- Preventing non-conformance should improve system performance
  - Proactive approach forces company to deal with non-conformances internally
  - Should provide defect reduction in the system operations
  - Should yield a more reliable system where technical performance is increased
  - Can aid in a higher system performance



Discussion of findings

- Rationale for why the company work in the current manner
  - First time creating this type of system
- Long-term benefit lies in improving the system development process through a proactive quality approach
  - Implementation of proposed quality tools will require extra initial investments
  - These initial investments will in long term save costs used on non-conformances
- Implications for systems engineering (SE)
  - Proactive approach forces companies to focus on other SE related activities than just quality assurance
  - Research illustrates how and where system developers can use the described tools in the system development process
- Implications for industry
  - Research is applicable to other young SE companies
- Limitations of study
  - Employees mislead by survey options
  - Illustrated use of Quality Function Deployment and design risk assessment is a theoretical study

Conclusion and further work

- System effectiveness
  - Quality tools improve on systems engineering related activities
  - Improved system engineering related activities should improve system effectiveness
- System performance
  - Proactive quality approach forces company to deal with non-conformance before system becomes operational
  - Lead to defect reduction and improved technical performance
  - Can aid in higher system performance
- Quality focus
  - Pursue perfection to quality at every phase of system development process
  - Proactive approach from moment a company considers creating a new system, until it is operational
- Further work
  - Could not identify the reason for why water samples showed higher values exiting the system, than what was entering
  - Research can serve as a reference point to future studies

Acknowledgements

- Employees of the company
- Customers from Bane Nor and Mesta

Questions?