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A System Engineering approach to automation of sorting crates.

Master's thesis by Armand Misund - 2021

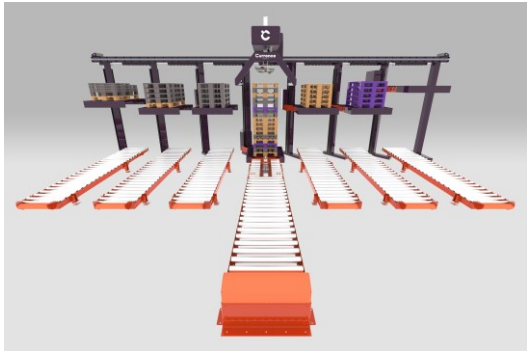
Problem

Introduction
Literature review
Methodology
Analysis
Evaluation
Conclusion

- Manual sorting process of crates, quality check and sorting by size.
  - 300 crates sorted per hour today.

Unsorted crates

- Currence Robotics will automate the process using its own technology.
  - Aim to sort 1200 crates per hour.



Existing technology

Motivation

Automation of logistics is today a growing industry in Norway, and to be part of this development is exciting and useful.

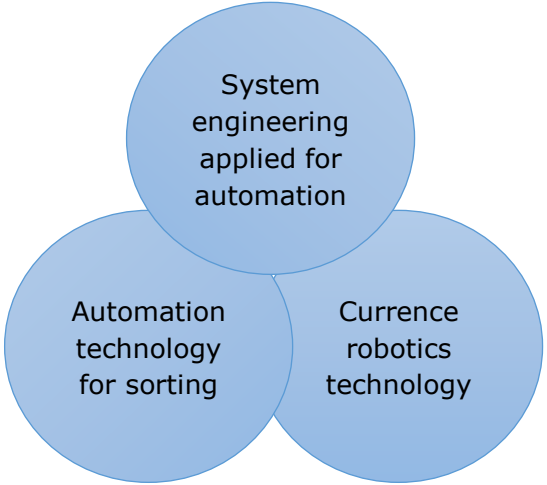
Objectives

The goal of this task is to simulate the benefits of automating a currently manual process.

Sorted crates

Scope of work

Using Systems Engineering to automate a process using Currence Robotics technology.



Scope graphical presentation

Research questions

- RQ1: How can we apply system engineering to organise the product, and the process for the automation of sorting?
- RQ2: How can we use Currence robotics technology to propose a solution?
- RQ3: How can we quantify efficiency (time), and cost by using Currency Robotics technology on the sorting process?

Literature review

Introduction

Literature review

Methodology

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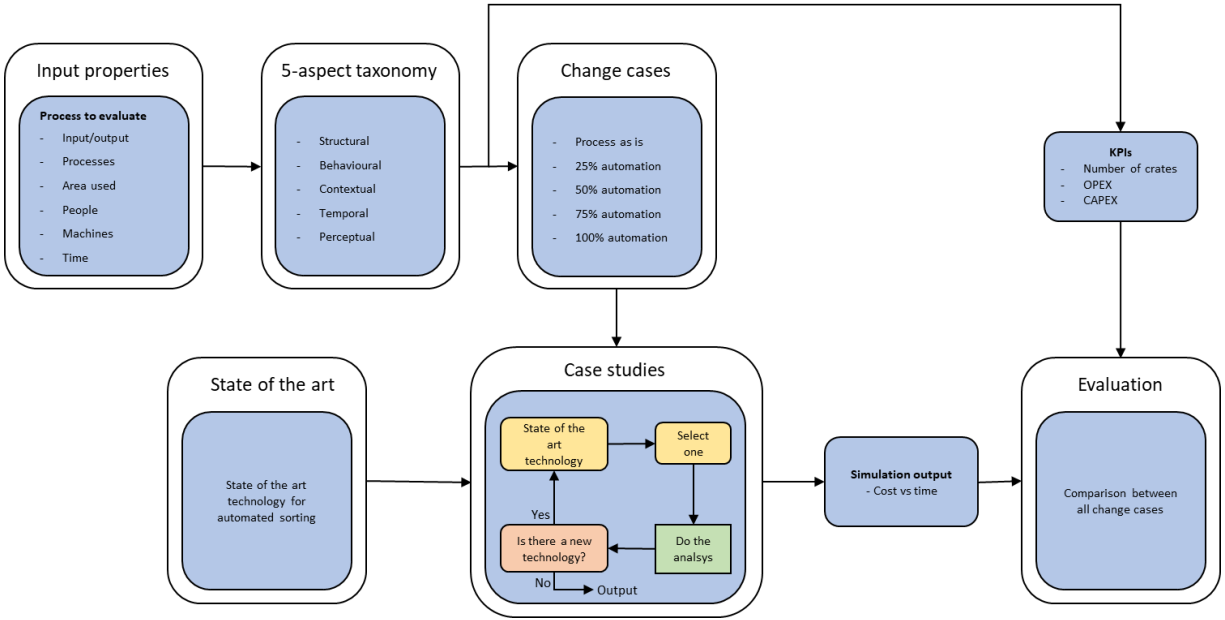
- Systems engineering applied for Automation
- Automation technology for sorting
- Currence Robotics technology for sorting

Currence Robotics technology

Methodology

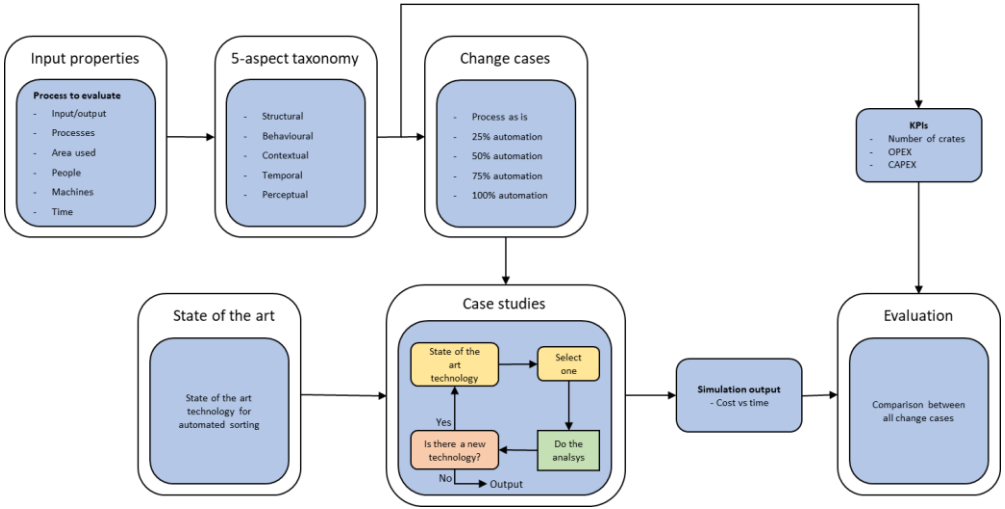
Based on Systems Engineering, a method was created to map the manual process and various solution proposals.



Methodology

Input properties

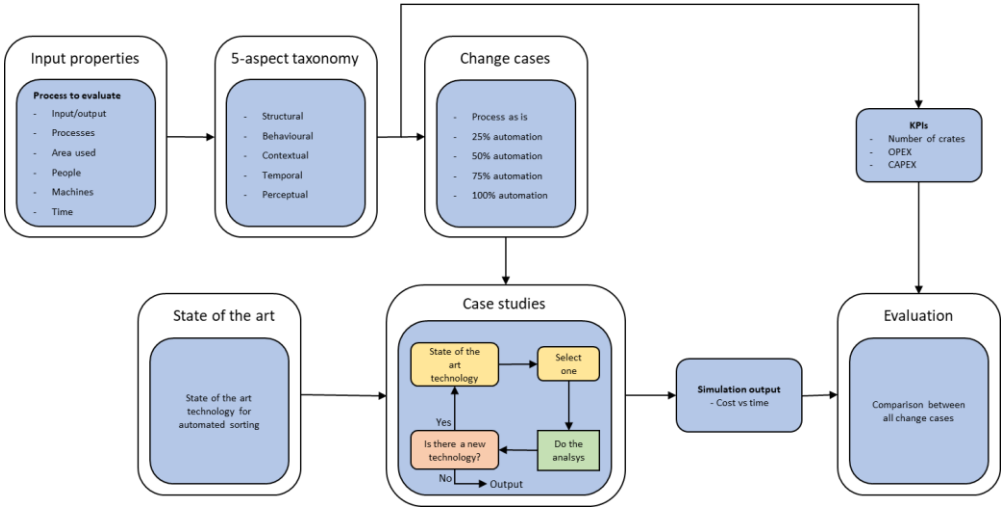
The selected process must be thoroughly mapped and described to understand the background, objectives and being able to present the input and output of the process.



Methodology

5 -aspect taxonomy

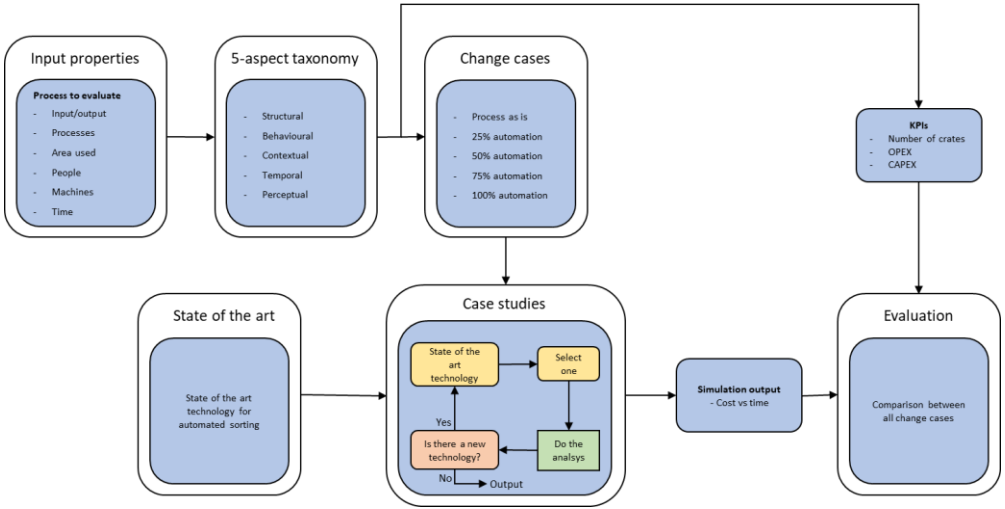
To understand the sorting process as good as possible, the 5 -aspect taxonomy is used. The 5 taxonomies are: Structural, Behavioural, Contextual, Temporal, and Perceptual.



Methodology

Change cases

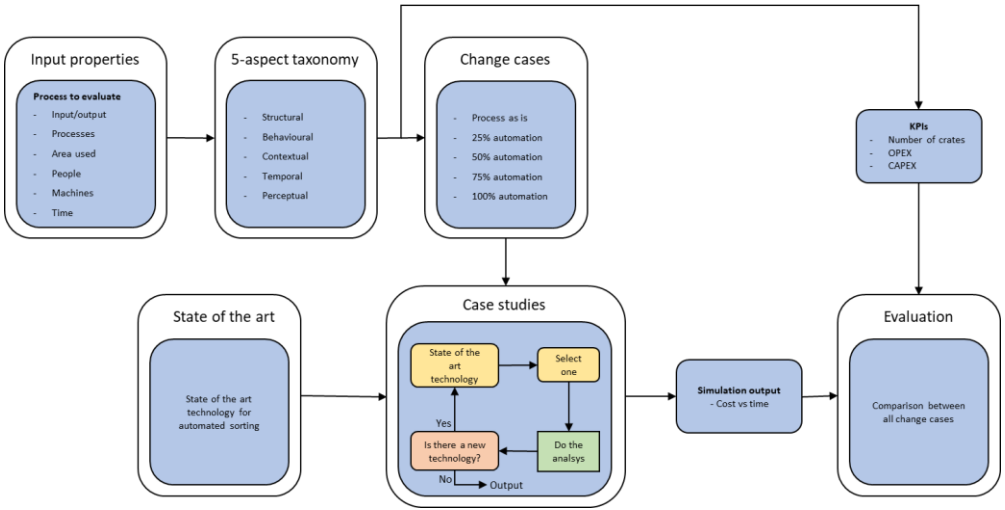
The selected process will be the basis for three different cases with gradually implementation of automation.



Methodology

State of the art technology for sorting

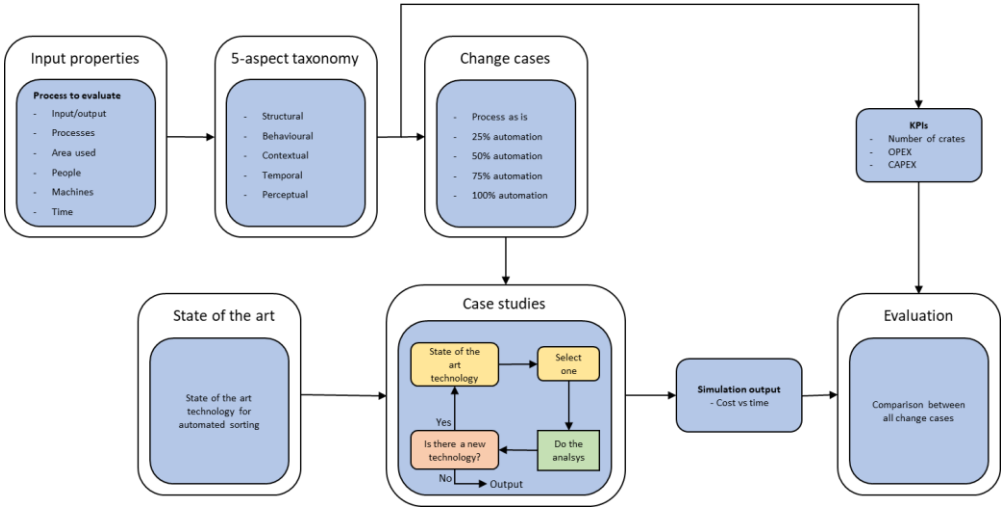
Based on the literature review, automation technologies will be suggested.



Methodology

Case studies

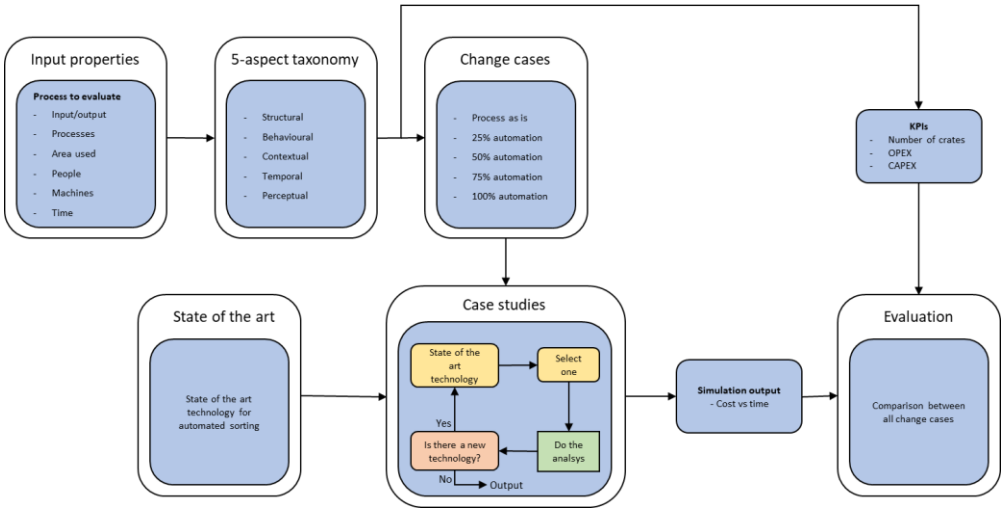
The three change cases will be matched with the state-of-the-art technology for sorting.



Methodology

System performance (KPIs)

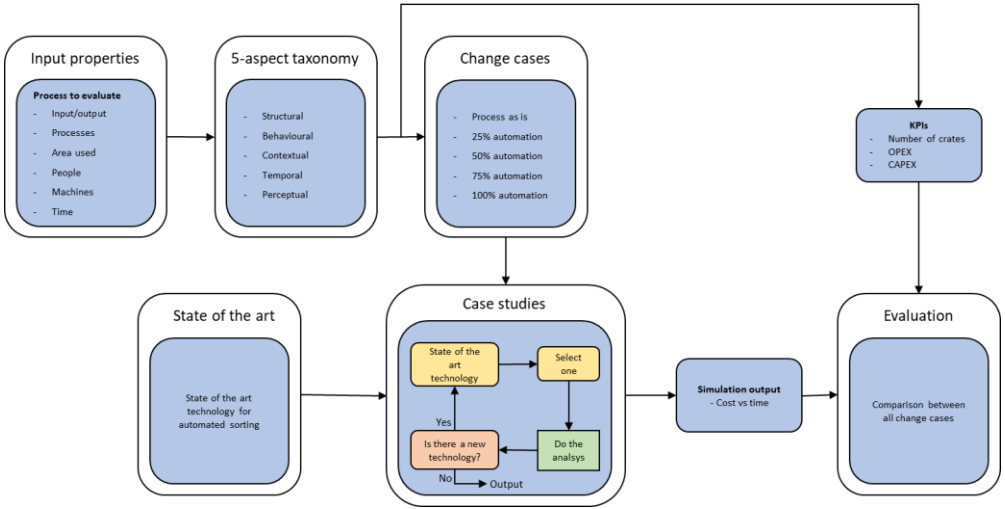
The key performance indicators (KPIs) are agreed with selected shareholders based on conversations and interviews.



Methodology

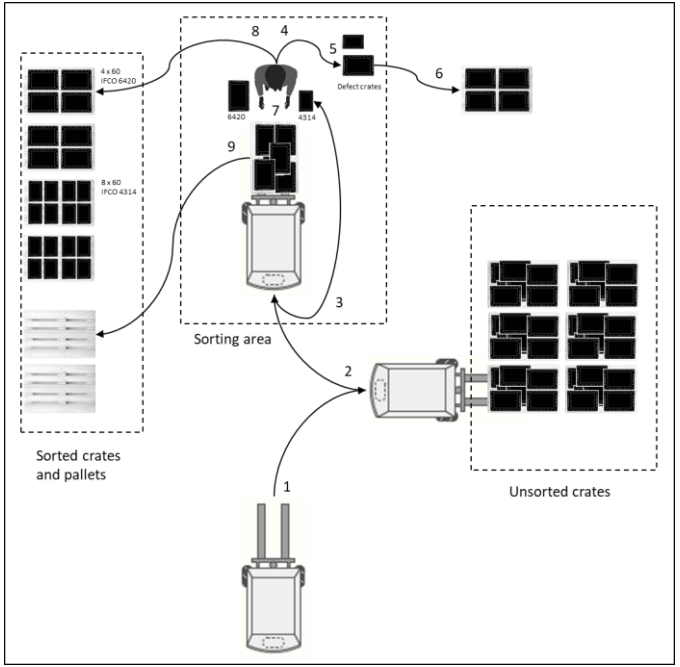
Evaluation

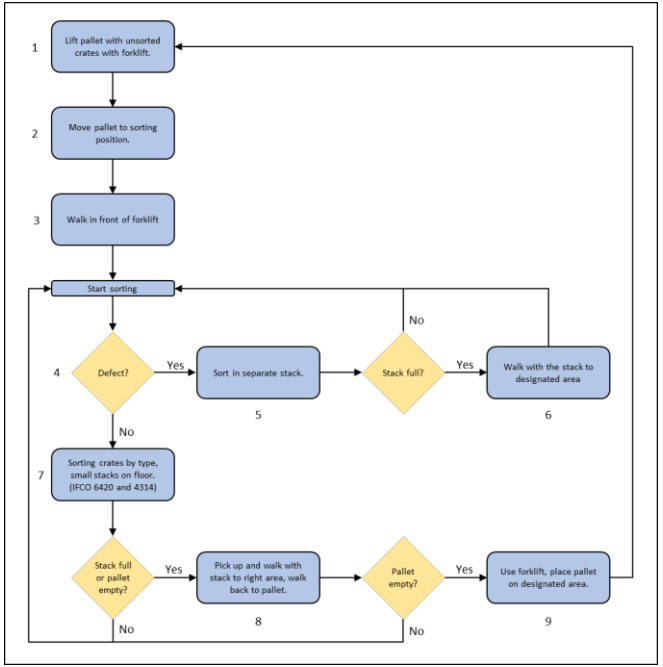
Along with the results from the 5-aspect taxonomy, KPI calculations for the current change case are presented in a Gantt chart.



Analysis

All cases are presented with a block diagram and a flow chart of the process.





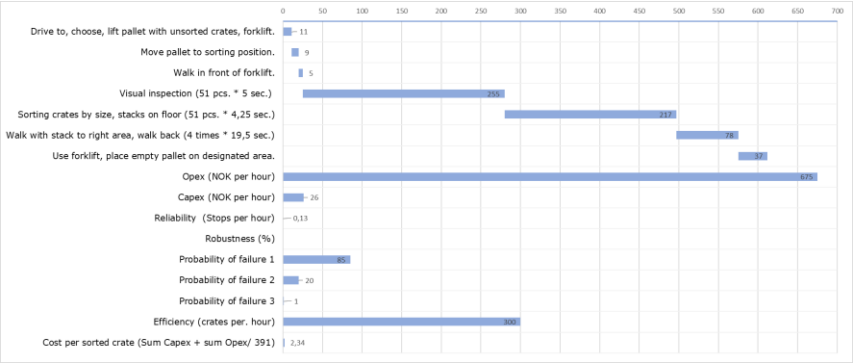
Manual case block diagram and flow chart.

Analysis

And results from the 5-aspect taxonomy and KPI calculations.

	Task	Sum duration	Duration sec.	Unit
1	Drive to, choose, lift pallet with unsorted crates, forklift.	0	11	sec.
2	Move pallet to sorting position.	11	9	sec.
3	Walk in front of forklift.	20	5	sec.
4	Visual inspection (51 pcs. * 5 sec.)	25	255	sec.
7	Sorting crates by size, stacks on floor (51 pcs. * 4,25 sec.)	280	217	sec.
8	Walk with stack to right area, walk back (4 times * 19,5 sec.)	497	78	sec.
9	Use forklift, place empty pallet on designated area.	575	37	sec.
1	Opex (NOK per hour)		675	NOK
2	Capex (NOK per hour)		26	NOK
3	Reliability (Stops per hour)		0,13	Stops per hour
4	Robustness (%)			
	Probability of failure 1		85	%
	Probability of failure 2		20	%
	Probability of failure 3		1	%
5	Efficiency (crates per. hour)		300	crates per. hour
6	Cost per sorted crate (Sum Capex + sum Opex/ 391)		2,34	NOK per crate

5-aspect taxonomy results and KPI values .



Gantt-chart of results

Evaluation

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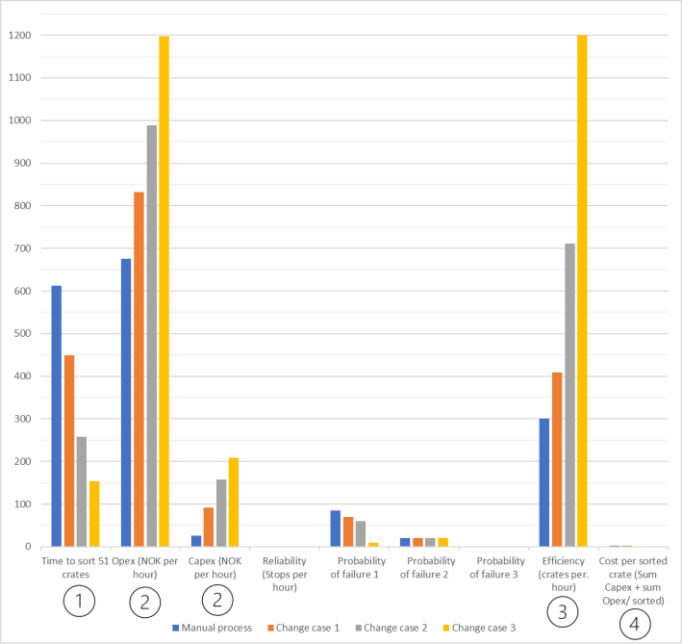
5-aspect taxonomy results and KPI calculations comparison between manual- and the change cases



From the left side in the figure

1. Time to sort decrease with implementation of automation.
2. Costs, both Opex and Capex increased with automation.
3. Efficiency increased 400% from manual case to fully automated, change case 3.
4. Cost per sorted crate decreased by 50%

Evaluation

Efficiency (crates per hour) and cost per sorted crate.

Task	Efficiency (crates per. hour)				Unit
	Manual process	Change case 1	Change case 2	Change case 3	
Efficiency (crates per. hour)	300	409	712	1200	crates per. hour
Increase in number of crates sorted between cases.		36	74	69	%
Increase between manuel case and case 3				400	%
Cost per sorted crate (Sum Capex + sum Opex/ sorted)	2,34	2,26	1,61	1,17	NOK per crate
Decrease in cost between cases.		-3,30	-29	-27	%
Decrease between manuel case and case 3				-50	%

The efficiency increased from 300 in the manual case to 409 and 712 in change case 1 and 2. and ended in 1200 crates per hour in change case 3.

With the efficiency increase, the cost per sorted crate, sum of cost divided on sorted crates, decreased between the change cases.

Evaluation

Cost of sorting crates at different available volumes per hour.

Task	NOK per sorted crate			
	Manual process (300)	Change case 1 (409)	Change case 2 (712)	Change case 3 (1200)
Cost per sorted crate at **300** crates available per hour	2,34	3,08	3,82	4,69
Cost per sorted crate at 4**00** crates available per hour		2,31	2,87	3,52
Cost per sorted crate at **500** crates available per hour		1,85	2,29	2,81
Cost per sorted crate at **600** crates available per hour			1,91	2,35
Cost per sorted crate at 7**00** crates available per hour			1,64	2,01
Cost per sorted crate at 8**00** crates available per hour			1,43	1,76
Cost per sorted crate at 9**00** crates available per hour				1,56
Cost per sorted crate at 10**00** crates available per hour				1,41
Cost per sorted crate at 11**00** crates available per hour				1,28
Cost per sorted crate at 12**00** crates available per hour				1,17

The manual process sorts 300 crates per hour.
The fully automated case must sort 600 crates per hour to have the same cost as the manual per crate. It has a capacity of 1200 crates per hour and is profitable already after 600 crates per hour compared to today's manual solution.

Conclusion

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- The chosen method provided a good understanding of all processes.
- Given the validity of the results in this thesis, it is a good idea from Currence Robotics to automate this process.
- The good results for the automated solution include those operators who are already performing this process manually.
- The KPI Reliability (stops per hour) did not provide the feedback that was intended, as it proved difficult to calculate.
- Robustness [%, Probability of consequence] also proved to be a theoretically difficult exercise, it was somewhat better defined than Reliability, but still not good enough.

Acknowledgements

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