NTNU

Digitalization Challenges in Engineer to Order Manufacturing

a Norwegian perspective focusing on manufacturing logistics

Prof Jan Ola Strandhagen and collegues

Hope to welcome to AIM 202X

www.smartlog.no

Strandhagen Båtbyggeri

n, Ole Trondson Sigerdd på garden Sigerset i 1849. Han hadde fem

han vart kalla i daglegopp hos tanta og onkegarden Årset i Veøy. Eg det slik at han var på var 10 år til han var ca. el.

rset hadde mykje skog bruk. Ola hadde derfor n sitt daglege arbeid r og materialar. Vi veit begynte med båtbygt er sannsynleg at det la han var på Årset. fortalt at det var vangardar i bygda å bygge mellom onnene.

g med Brit Slemmen 885 kjøpte dei garden Indre, og tok då som slektsnamn. Dei men fire av borna alder. Av dei som far min, Thorvald,

kan hugse av båtgjekk for seg her. r *Glimt*, som vart bygd i 1926. Eg var da fem år gammal. Eg hugsar også at det var folk frå Skarbøvika her i samband med båt. Det må truleg ha vore etter 1926.

For å skaffa fram fleire opplysningar om båtbyggeriet i Strandhagen, har eg bede naboen min, 92-åringen Karl Hovland, fortelje frå den tida. Han arbeidde der sjølv i periodar og har førstehands kjennskap til saka.

Karl fortel at Ola var i arbeid hos båtbyggar Hammerås på Vestnes, og var i 1874-75 med på å bygge den kjende seglskuta *Herrmann Lemkuhl*. Det er truleg at han hadde ein del erfaring frå før, for han vart tilbydd formannsjobb på dette oppdraget. Men ha seg tilbodet, då han mei ikkje var kompetent for op

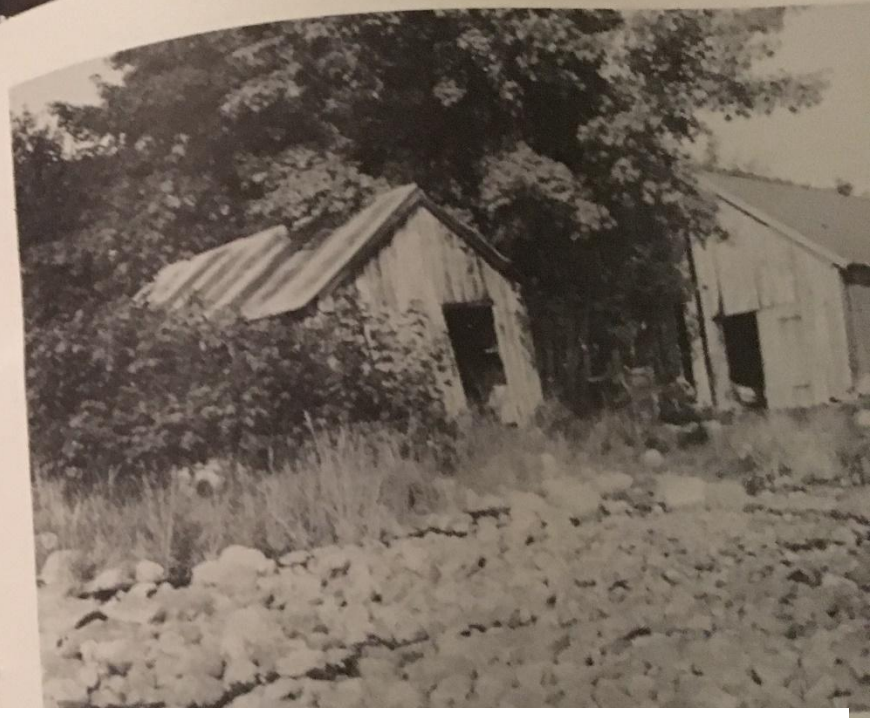
Etter at Ola hadde kjøpt hagen, begynte han å færingar og trerøringar i naustet. I den første tida var brørne hans, Trond og Kristoffer, med på dette arbeidet.

Men Ola hadde lyst til å prøve seg på større båtar. Han bygde derfor nytt naust eller arbeidshus på omtrent 8 x 15 m. Dette måtte på grunn av terrenget byggast med langsida mot sjøen. Det vart derfor noko tungvint når båtane skulle sjøsettast. Når plassen tillet det, vart båtane bygd inne, men nokre større båtar vart bygde ute.

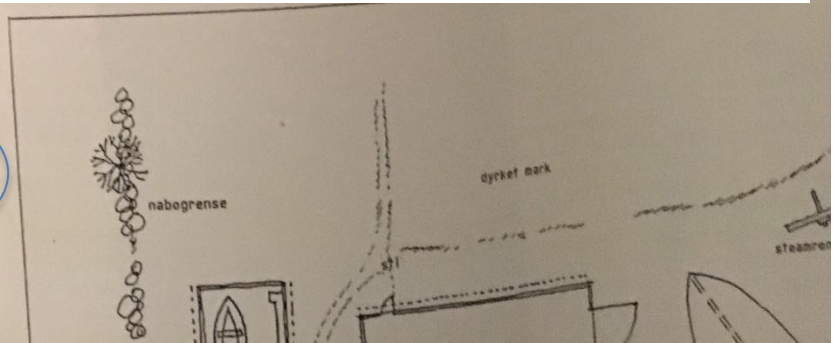
Karl nemner nokre av båtane han hugsar vart bygde her: I 1904 vart det bygd ein klinkerbygd dekksbåt for motor. Den vart bygd for 17 år gamle Nils Sandøy, seinare kjend under det legendariske namnet *Sjøfokk-Nils*. Så meiner han at det vart bygd ein 50 fot stor mudderpram. Prammen vart bygd i samarbeid med Nils Bolsønes, og skulle nyttast i Ålesund under gjenreisinga etter brannen i 1904. Vidare

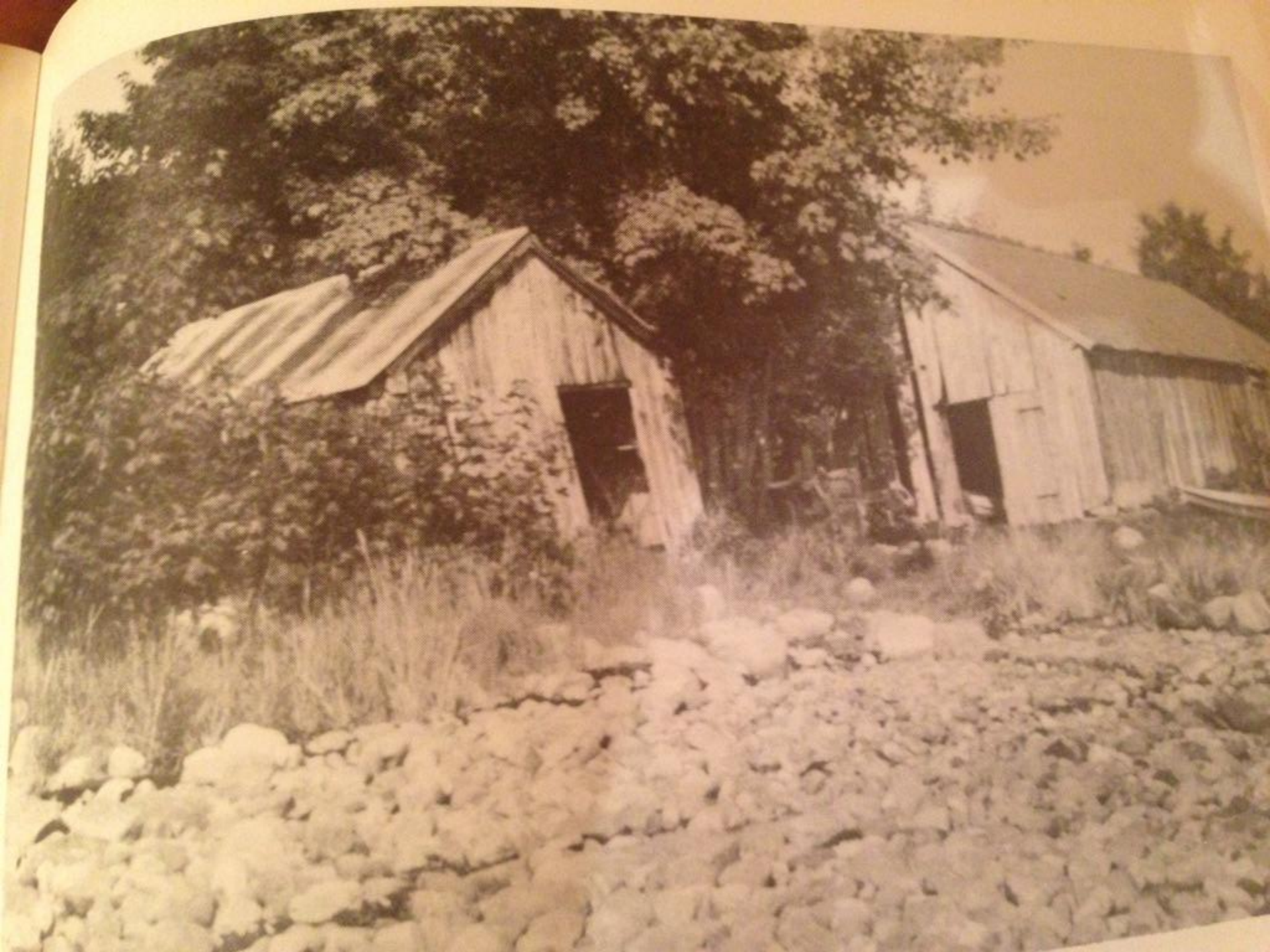
Knut Skarbøvik i Ålesund. Dette var kanskje den siste båten som vart bygd her.

Karl seier at Ola var kjend som ein dyktig båtbyggar. Han laga sjølv modellane sine, og hadde uvanleg godt handlag med det verktyet som vart nytta den gongen. Han var også interessert i «tekniske hjelpemiddel», og laga kvernkallar og kvisthoggarar til eige bruk og til naboar. Han sette skovlhjul på færingen for å få jamnare drag

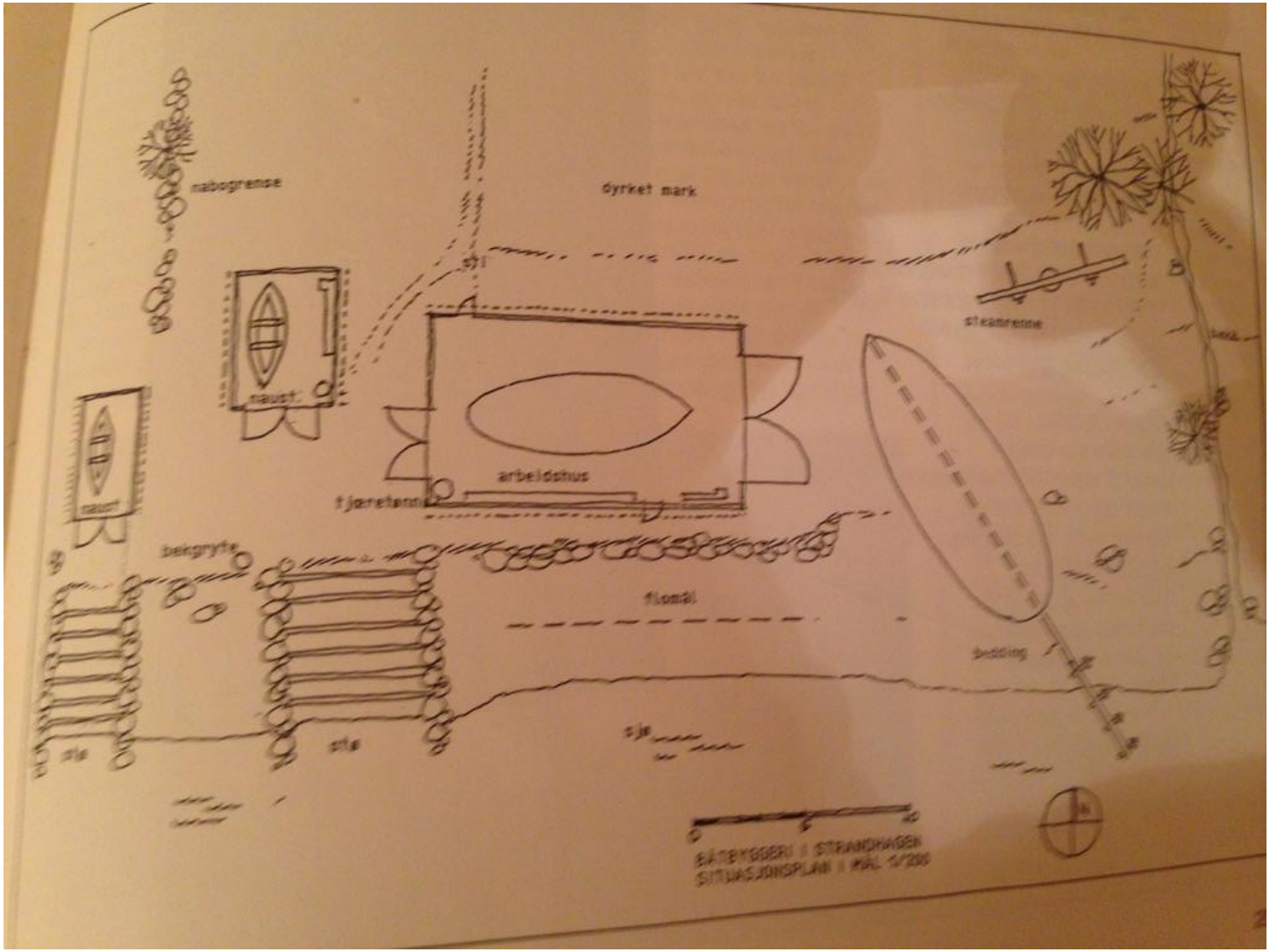


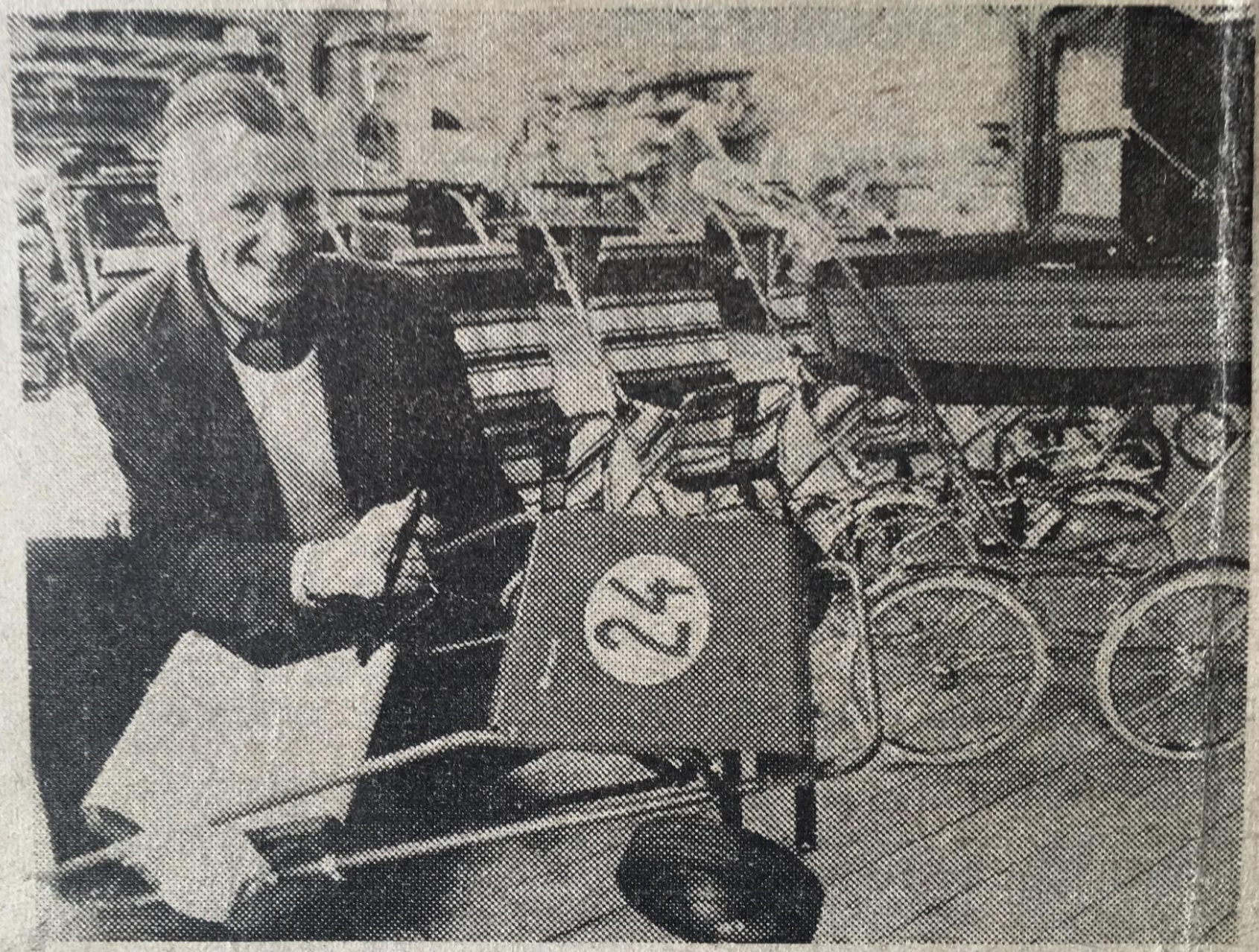
Not enough capacity nor capability





«verftet»..


nabogrense
dyrket mark
arbeidshus
fjæreteinn
bekgryte
flomål
sjø
BÅTBYGGERI I STRANDHAGEN
SITUASJONSPLAN I MÅL 1:200



Driftsingeniør Odd Strandhagen med noen av produktene, barnevog-


Geeps


Geepa

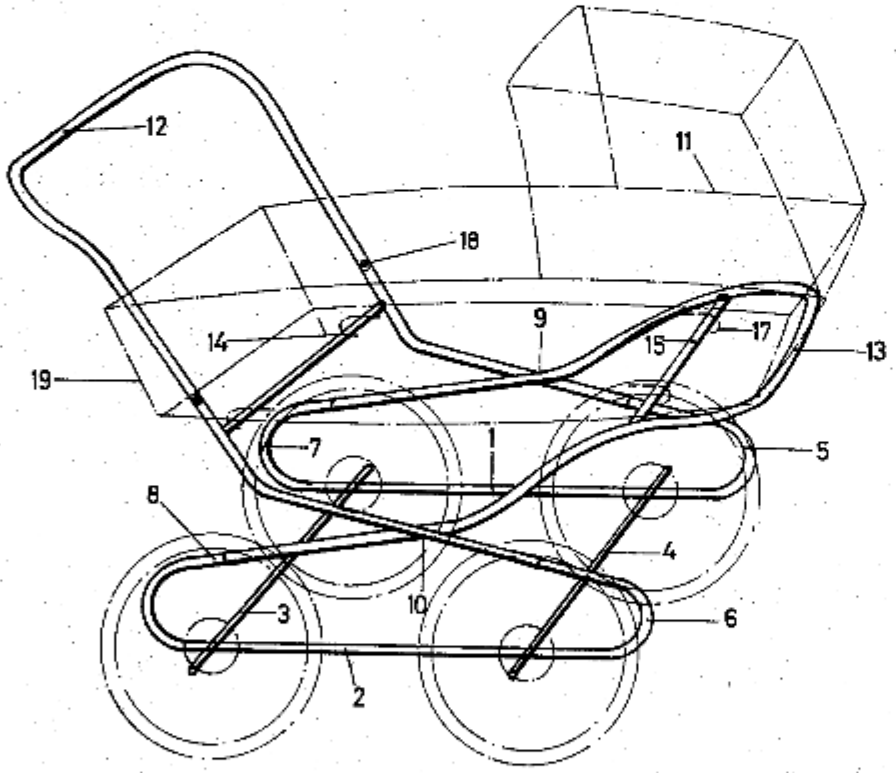


Fig. 2

INVENTOR.
ODD STRANDHAGEN

BY Stevens, Davis, Miller & Mosher

ATTORNEYS

NTNU

Norwegian University of Science and Technology

Trondheim, Norway

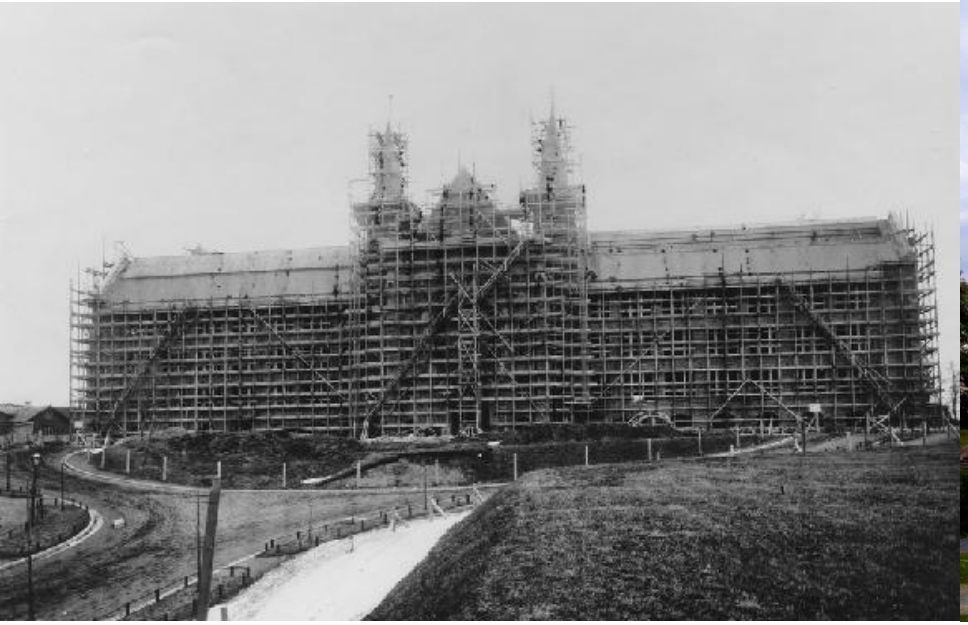


Photo: Schrøder, Trondhjem

Photo: Mentz Indergaard, NTNU Info

1905-1909

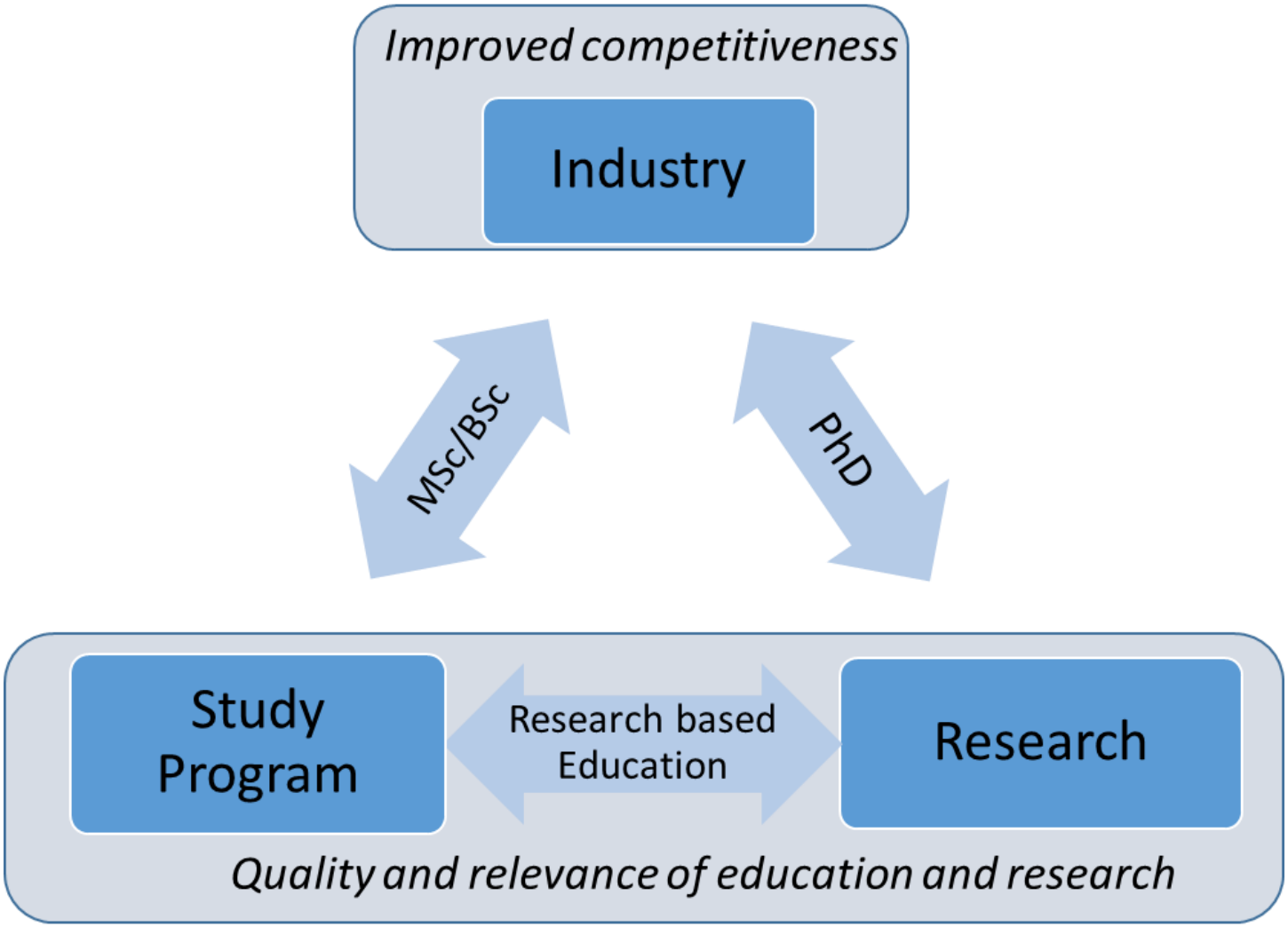
1910 -2019

38 000 Students Full range university

Norways leading university in technology

Campus in Trondheim, Ålesund and Gjøvik

How we work


Improved competitiveness
Industry
MSc/BSc
PhD
Study Program
Research based Education
Research
Quality and relevance of education and research

PIPELIFE Pipes for life

PIPELIFE


AX104
ULSTEIN AX104

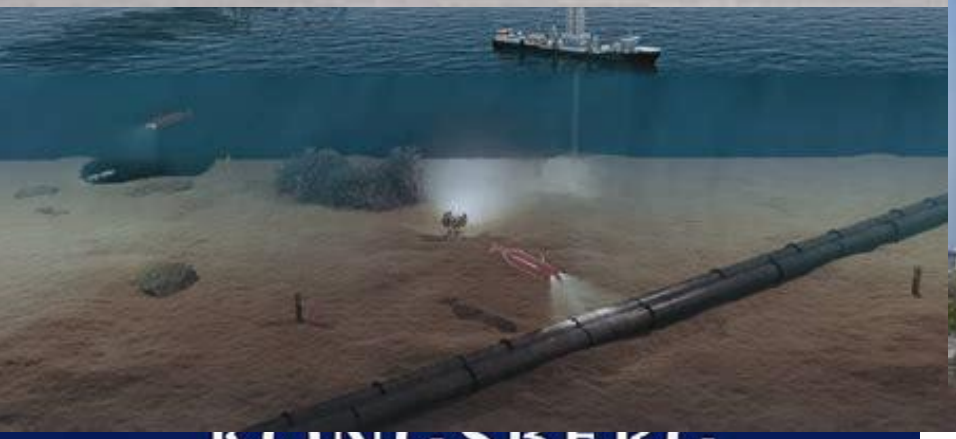
Raufoss™
COUPLINGS

HEXAGON
RAUFOSS

Nammo

NEUMAN
ALUMINIUM
RAUFOSS

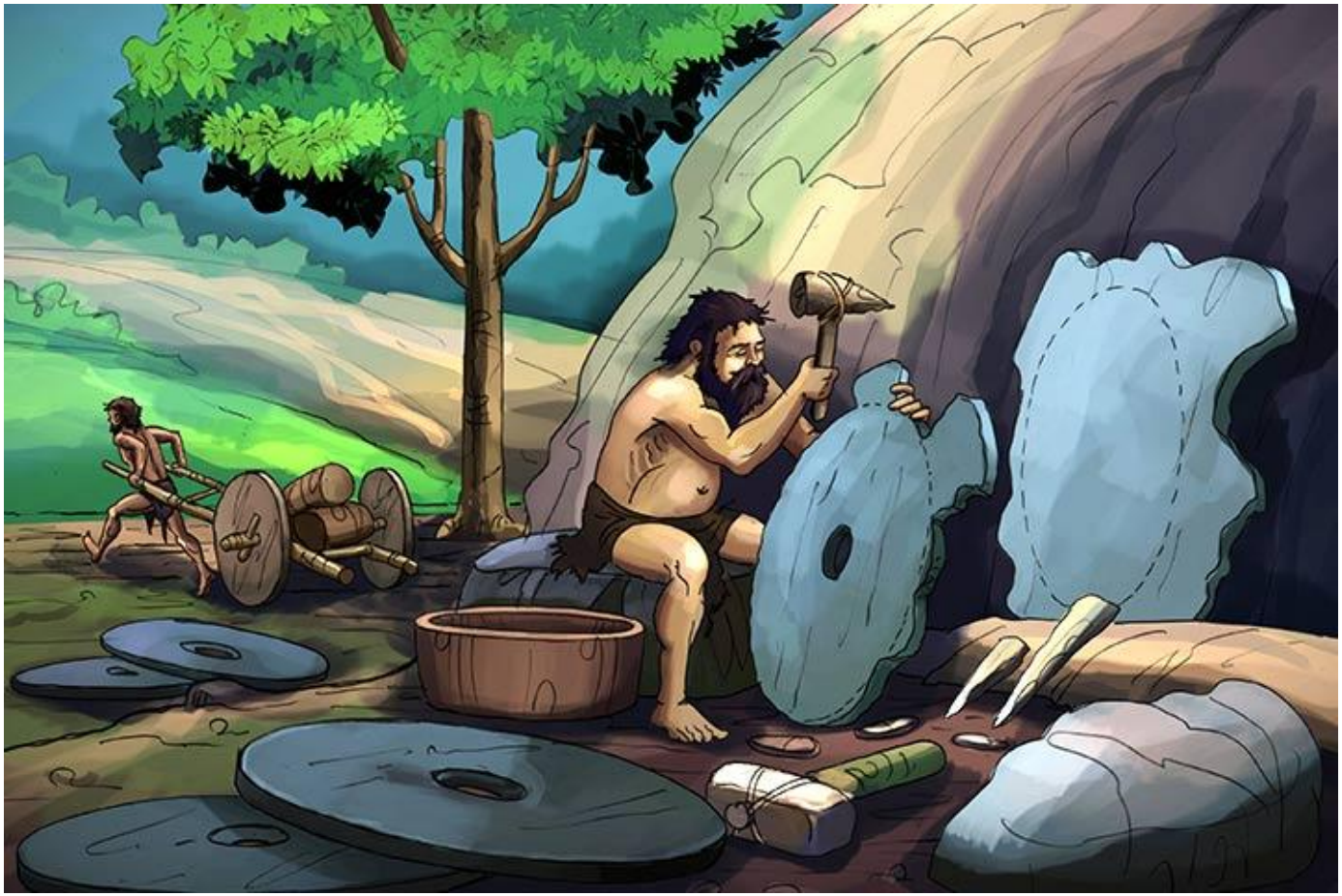
BENTELER



ology

KONGSBERG

Lookback to production…




GALILEO GALILEI

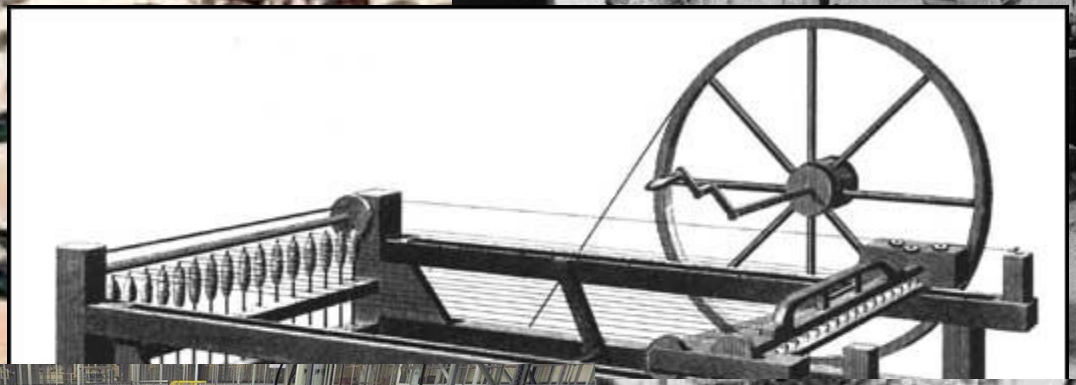
The yard Arsenale di Venezia (1500..)

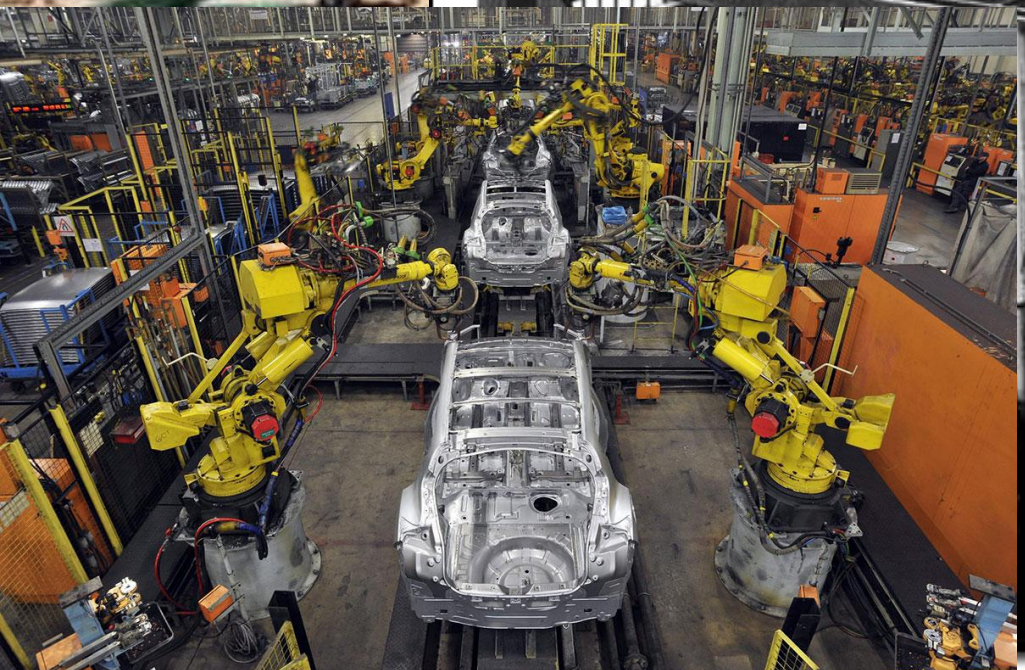
- Main gate built in 1460
- Outfitting and producing fully equipped **customized** vessels at the **rate of one per day**
- The ability to **mass-produce** galleys on an almost assembly-line process
- Standardised components
- Unique design

http://www.arsenaledivenezia.it/main/gallery.aspx?gallery=23-tese arsenale vecchio

Mass customisation


personalised
ME



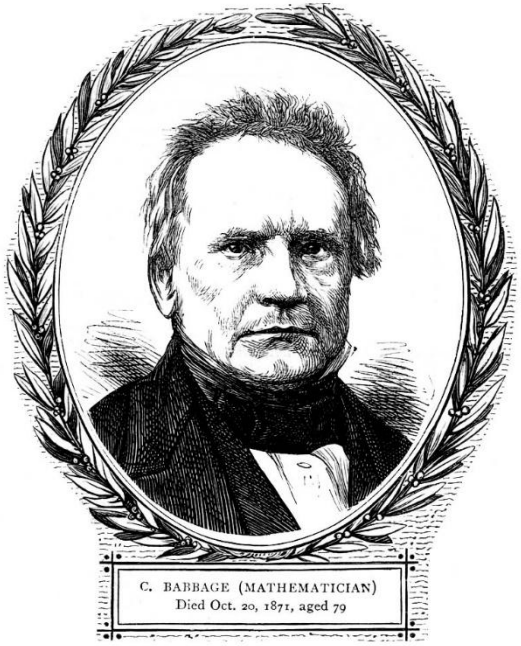


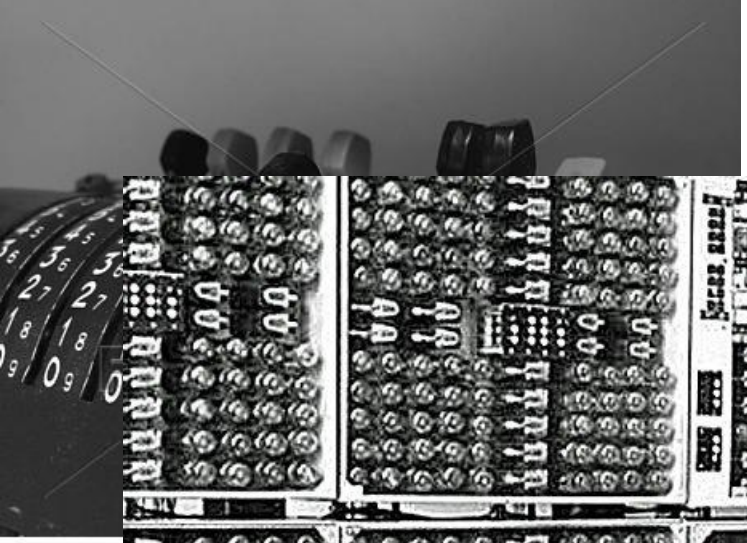

An Assembly Line
of the
Ford Motor Company

Charles Babbage (The Father of Computers) in 1834 :

"... I was sitting in the rooms of the Cambridge Analytical Society, my head leaning forward on the table in a kind of dreamy mood, with a table of logarithms lying open before me. Another member, coming into the room, and seeing me half asleep, called out, "Well, Babbage, what are you dreaming about?"

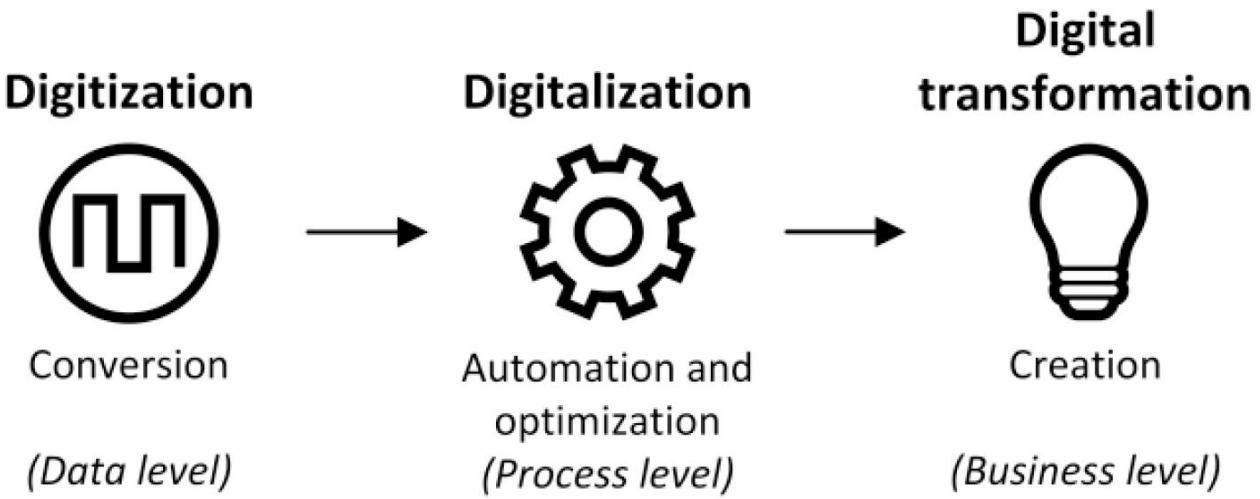
"I am thinking that all these log tables might one day be calculated by machinery "





Some possible definitions..

- **Digitization**: The conversion from analog format into a digital format.
- **Digitalization**: The use of digital technology to automate data handling and optimize processes
- **Digital transformation**: Creating new business opportunities through the use of digital data and technology



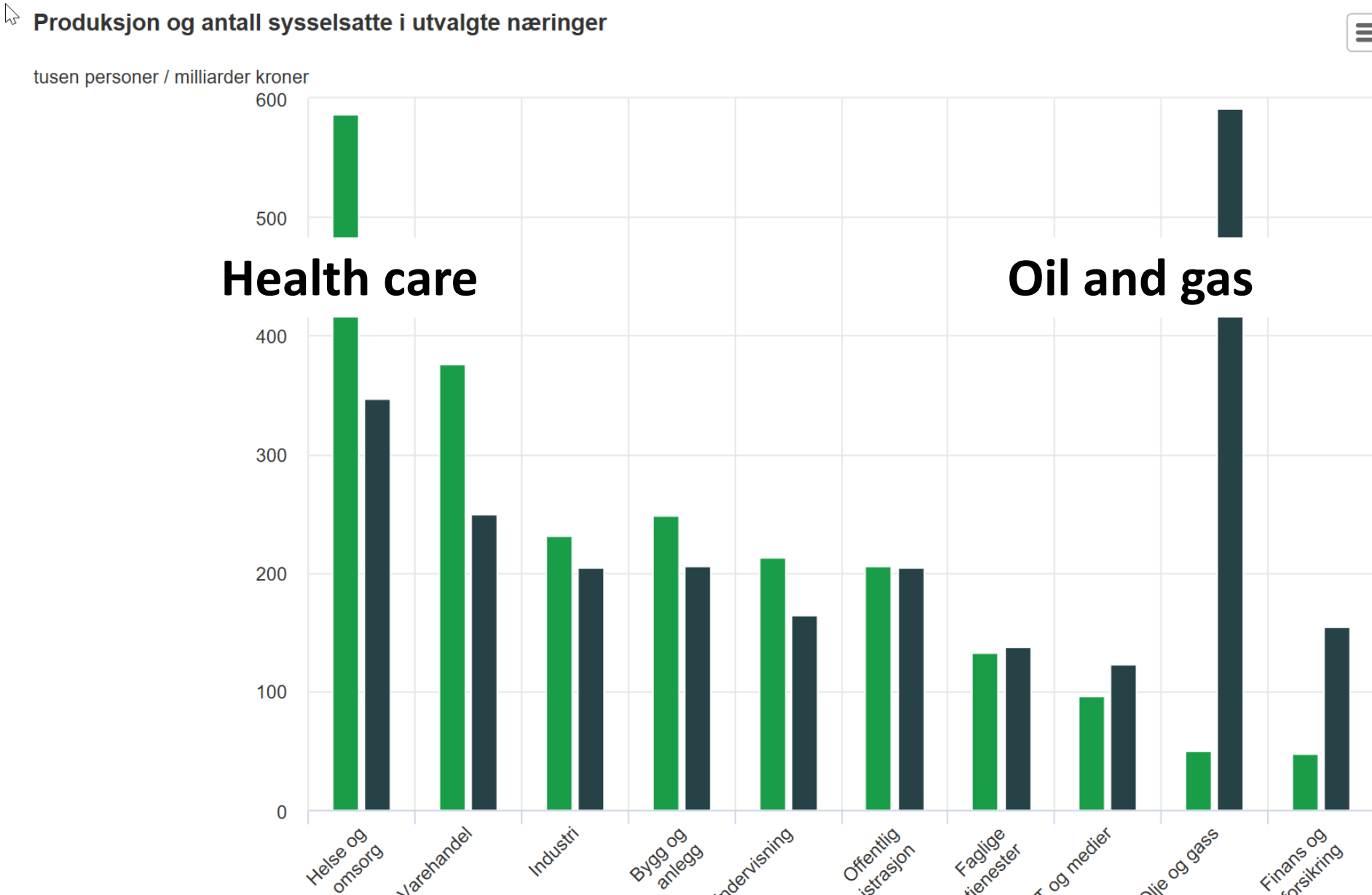
(Buer et al., 2018)

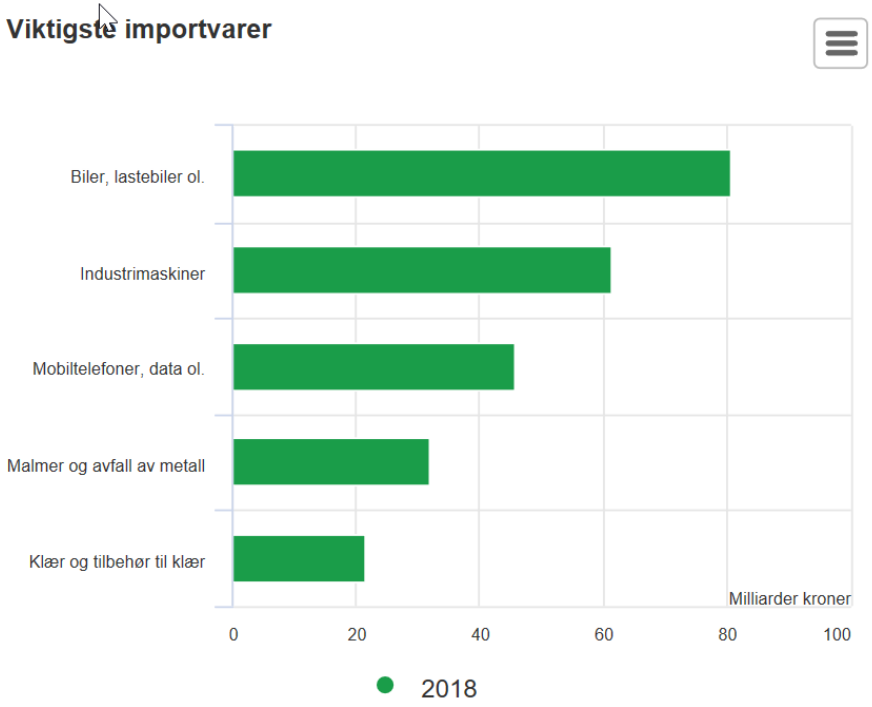

B
Navn Navnesen
Adresseveien 123
1234 NORGESVIKA

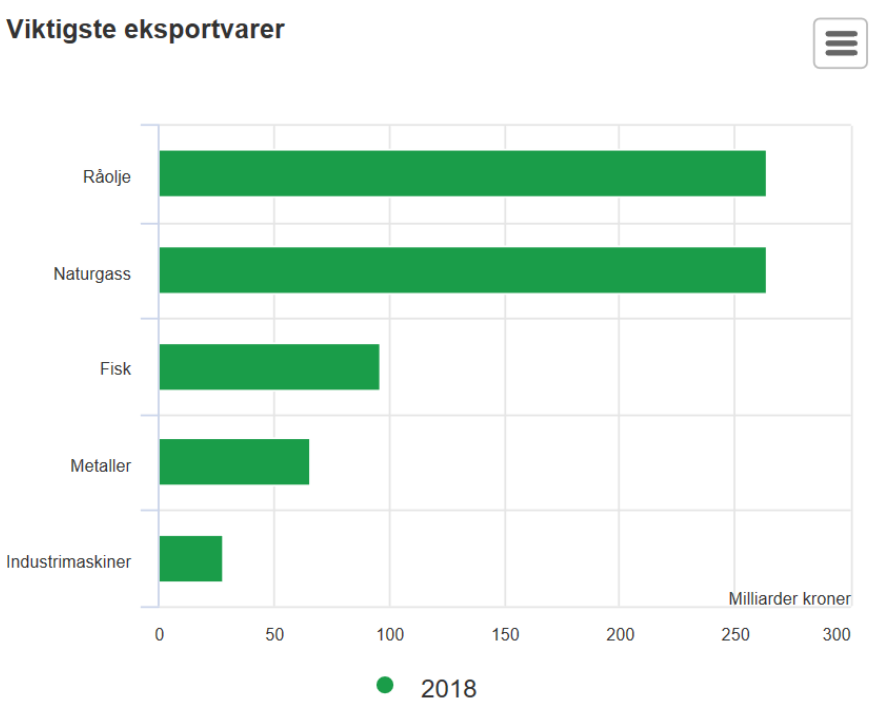

GROUP 3
SEAT 24F

And Norway ?

Value creation in Norway




Viktigste importvarer
Biler, lastebiler ol.
Industrimaskiner
Mobiltelefoner, data ol.
Malmer og avfall av metall
Klær og tilbehør til klær
Milliarder kroner
0
20
40
60
80
100
2018


Viktigste eksportvarer
Råolje
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Fisk
Metaller
Industrimaskiner
Milliarder kroner
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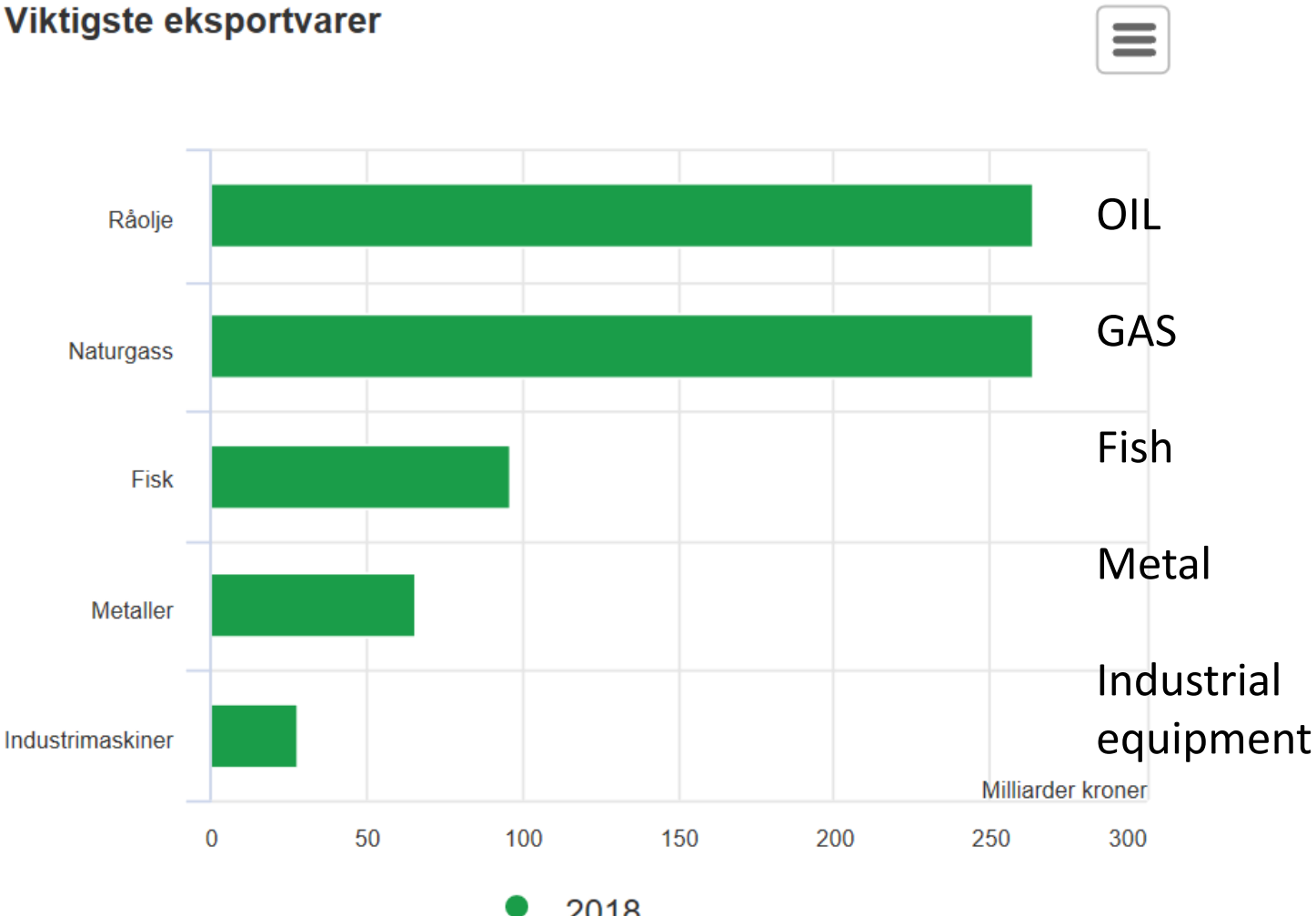
2018



OIL

GAS

Fish

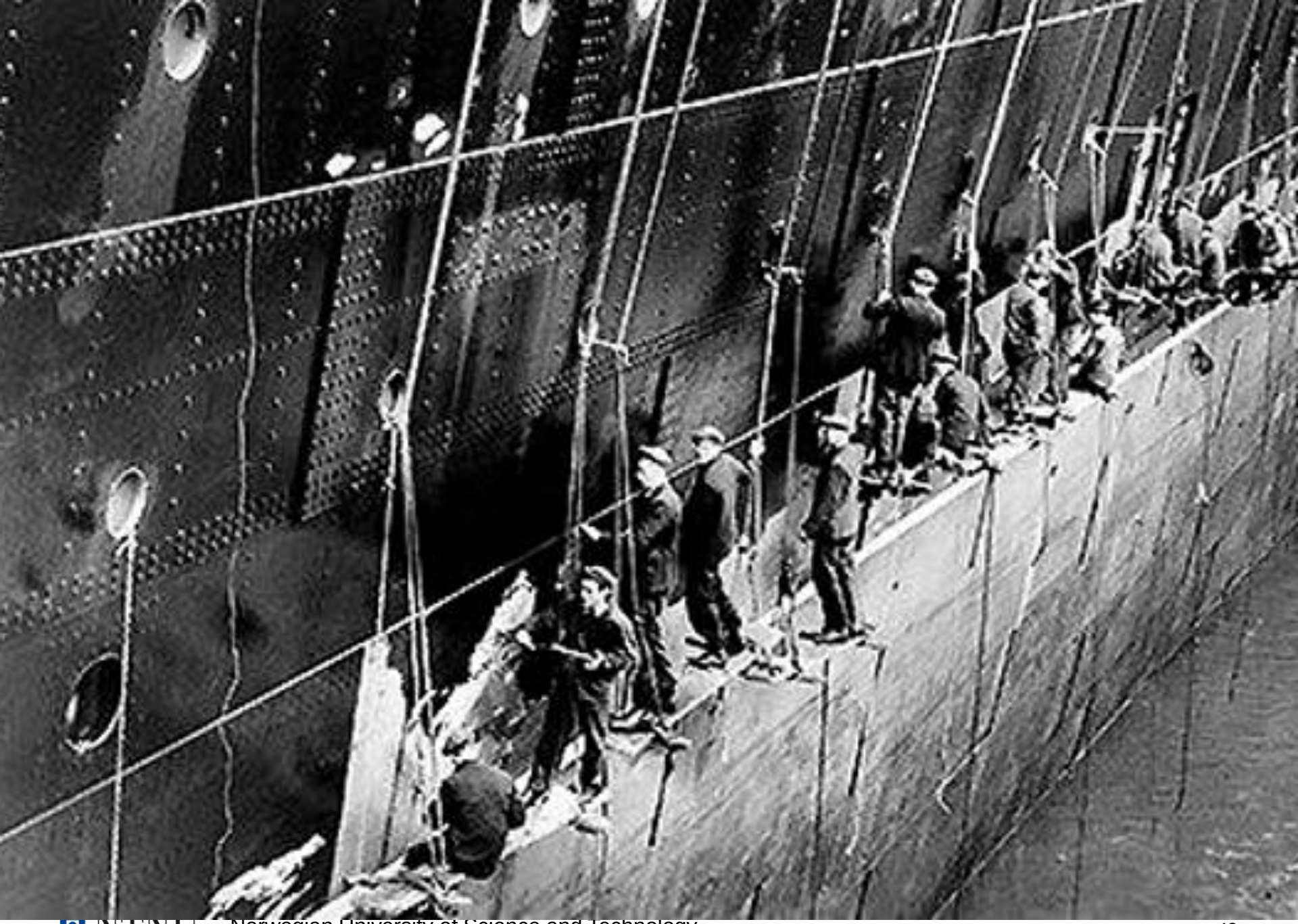
Metal

Industrial equipment


AX104
ULSTEIN AX104

Maximum lot size….2,5

Shipbuilding in 1930s



Shipbuilding now

Even in Korea…

Samsung Heavy Industries

Daewoo Shipbuilding & Marine Engineering

Hyundai Heavy Industries i Ulsan

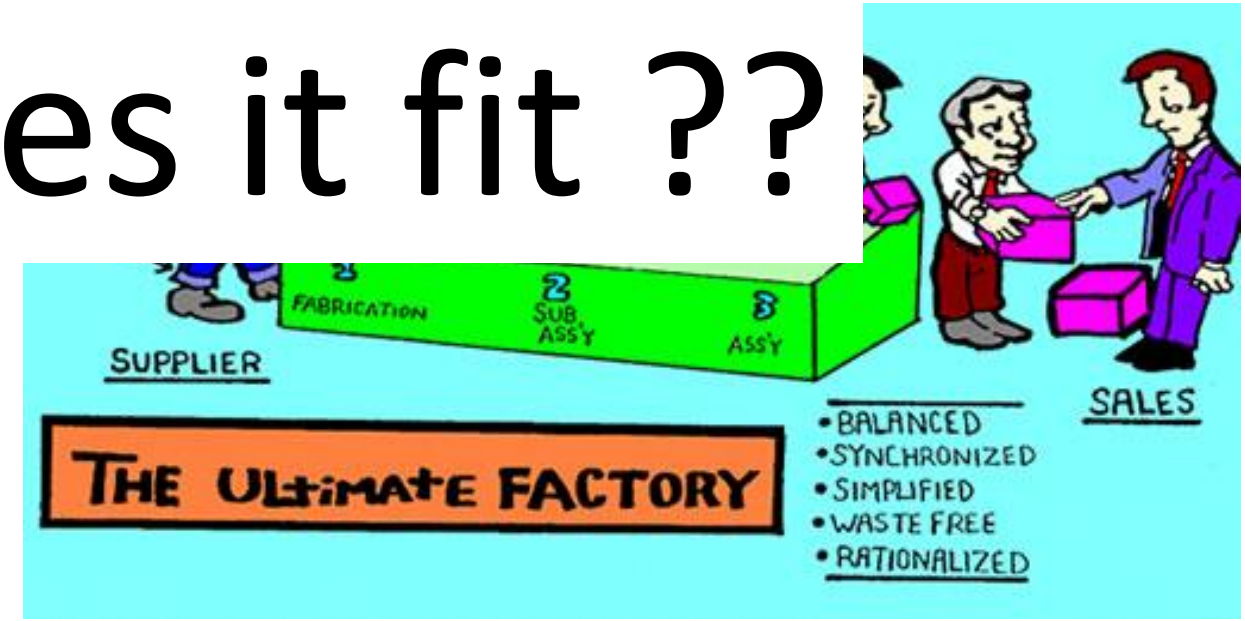
Toyota Production System

”The primary goal of the Toyota production system is to identify and eliminate waste and reduce costs”

Strives to

- Zero defe
- Zero inve
- Zero set-up
- Zero handling
- Zero downtime
- Zero leadtime
- Zero batches
  (Batch size of One)

Does it fit ??



It is unique and difficult challenge to create digital transformation in a situation with ……..processes where you make things you have not made before, you are not sure what they look like or how to process or where they should be delivered nor to whom ?

Production environments

Higher production volume, lower product variety

Complex customer products	Configure to order products	Batch production of standardized products	Repetitive mass production

Repetitiveness

Low volume, low standardization, high product variety
Complex products, designed and engineered to order, long lead time

Less complexity, assembled in small batches
Assemble- or make-to-order using standardized components
Shorter lead times

Make to stock of standardized products in medium to large orders
Products more complex and longer lead times than "repetitive mass production"

Products are made in large volumes on a repetitive and more or less continuous basis
Simple products (flat and simple BOM)

(Jonsson and Mattsson, 2003)

- Automation and robotization of repetitive, identical production and handling processes …. Solutions exist

- How to create digital transformation in a situation with ……..processes where you make things you have not made before, you are not sure what they look like or where they should be delivered nor to whom ?

- And with minimum of resource consumption, both in development and operation ?

Digitalized manufacturing logistics in engineer-to-order operations

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www.smartlog.no

Research motivation

- The need for coordination of material and information flows in ETO supply chains is significant [1] and tailored approaches are required for an effective and efficient management of manufacturing operations [2].
- The aspect of digitalization has not yet been sufficiently addressed for manufacturing logistics in this type of environment [3].
- Digitalization emerges as a way of managing complexity, making it a key focus area for the complex ETO manufacturing
- There is a need to investigate how digitalization can improve manufacturing logistics performance.
- Aims to identify how digital technologies can be adapted and applied in order to address the challenges in ETO manufacturing logistics.

Manufacturing logistics: the coordination of the operations related to the flow of materials through the manufacturing departments up to the production of the end product [5]

Characteristics

Product characteristics:

- Big sized, complex products with deep product structures [3, 11]
- High level of customization [9]
- High product variety and low volume on product level [2, 9]

Process characteristics:

- Manufacturing carried out as large projects in fixed position layouts [9]
- Highly integrated and overlapping activities [12]
- Frequent changes [11]
- Focus on flexibility [11]

Market characteristics:

- Customer order decoupling point located at the design stage [7]
- Fluctuations and uncertainty in mix and sales volume [10]
- Uncertainty in product specifications [10]

(Adrodegari et al., 2015, Amaro et al., 1999, Gosling and Naim, 2009, Hicks et al., 2001, MacCarthy and Fernandes, 2000, Semini et al., 2014, Sjøbakk et al., 2014, Stavrulaki and Davis, 2010, Wikner and Rudberg, 2005, Willner et al., 2016)

Case: Ulstein Verft AS (UVE)

- UVE is part of Ulstein Group ASA, a Norwegian industrial group with activities in ship design and shipbuilding.
- Designs and builds highly customer-specific vessels:
  - advanced offshore vessels such as supply vessels, anchor-handling vessels, offshore construction vessels and seismic vessels
  - Ferries, expedition cruise ships, yachts and passenger ships,
  - Service Operation Vessels (SOVs) for the offshore wind industry

Color Hybrid – RoPax ferry

National Geographic Endurance – polar expedition cruise ship

Island Venture – Offshore construction vessel

Nexans Aurora – cable laying vessel

Blue King / Farland – Platform supply vessel

Polarcus Adira: seismic research vessel

Source: ulstein.com/shipreferences

Shipbuilding at UVE

- "Outfitting yard"
  - UVE is the shipyard responsible for outfitting the ships delivered by the Ulstein group.
  - The hull production is carried out at a foreign yard, before the hull is towed to UVE in Ulsteinvik, Norway.
  - Dry dock outfitting and quay side outfitting

Source: ulstein.com

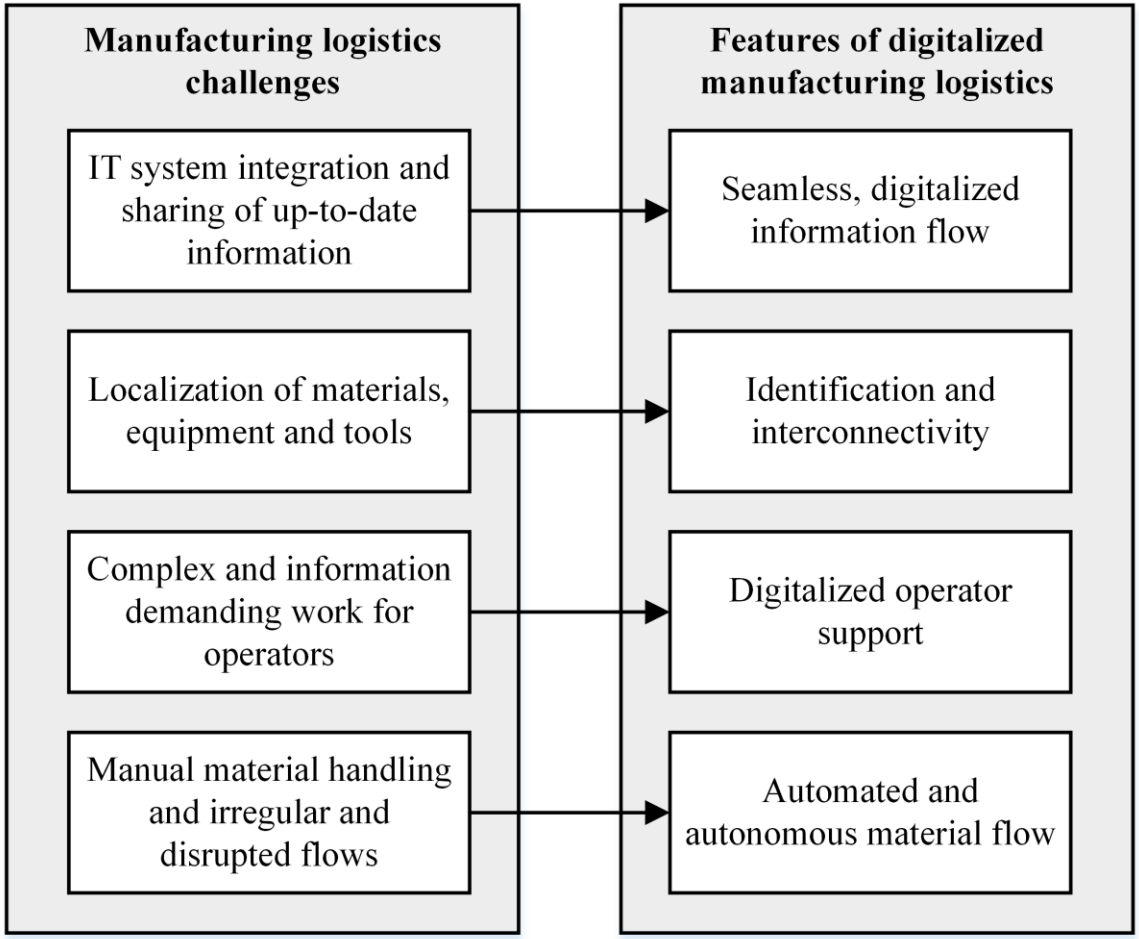
Manufacturing logistics challenges at UVE (I)

- Highly complex material and information flow related to outfitting activities with non-repetitive and non-routine work processes.
- Processes are prone to disruptions due to changes occurring after the outfitting activities has started.
- Challenging to achieve the tight integration of IT systems needed for efficient outfitting of the ships.
- Paper-based documentation of product models and drawings are critical sources of information for operators
- Operators have a particularly important role in performing outfitting activities
  - standardization and automation of processes is difficult due to the non-repetitive type of work.
- Many operations are manual
  - production processes, material handling and internal transportation of materials.
- Providing the required information to operators is complicated when changes occur, as models and drawings then must be updated accordingly.
- Difficult to have an overview of the yard from a manufacturing logistics perspective as operations are spread across a vast area.
- Materials, tools and equipment are geographically dispersed – operators spend a considerable amount of time walking to collect or search for them.

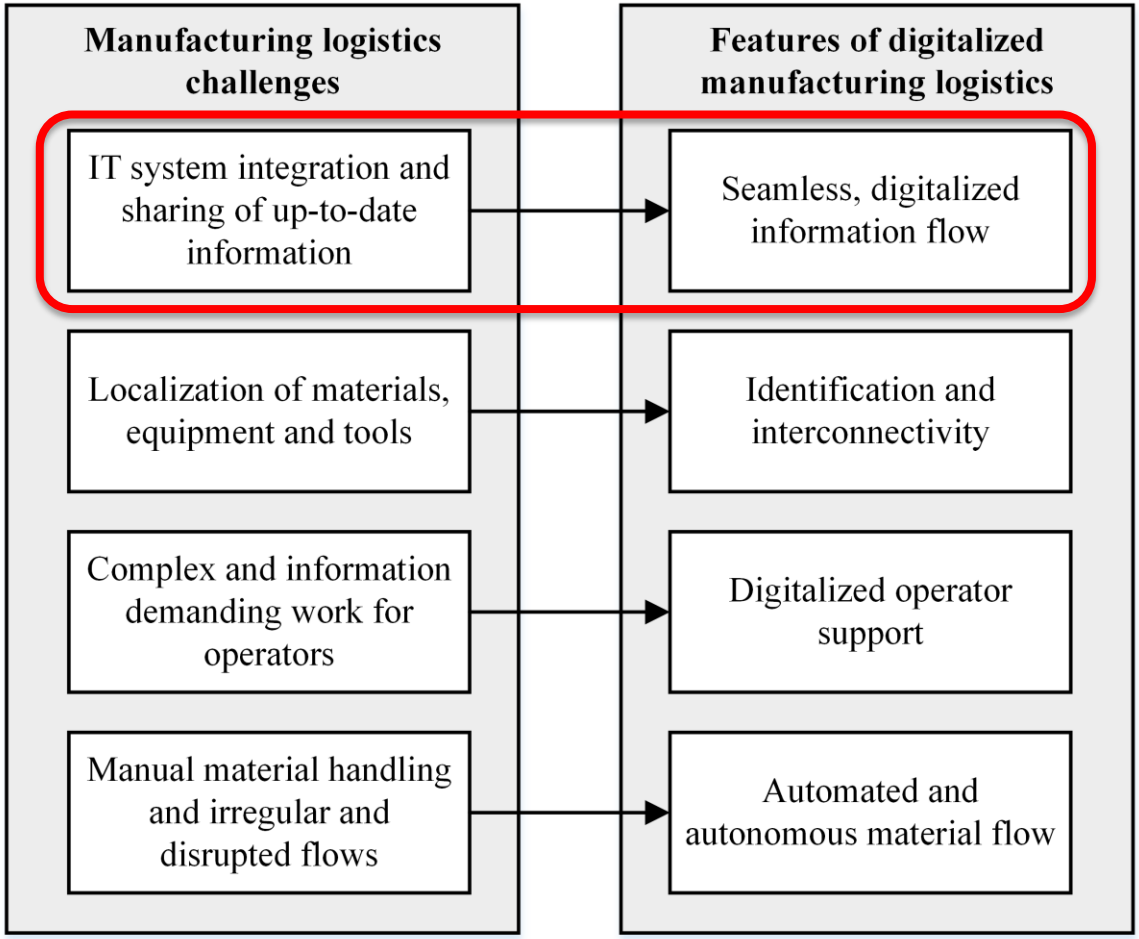
Manufacturing logistics challenges at UVE (II)

- IT system integration and lack sharing of up-to-date information
- Localization of materials, equipment and tools
- Complex and information demanding work for operators
- Manual material handling and irregular and disrupted flows

Features of digitalized manufacturing logistics in ETO

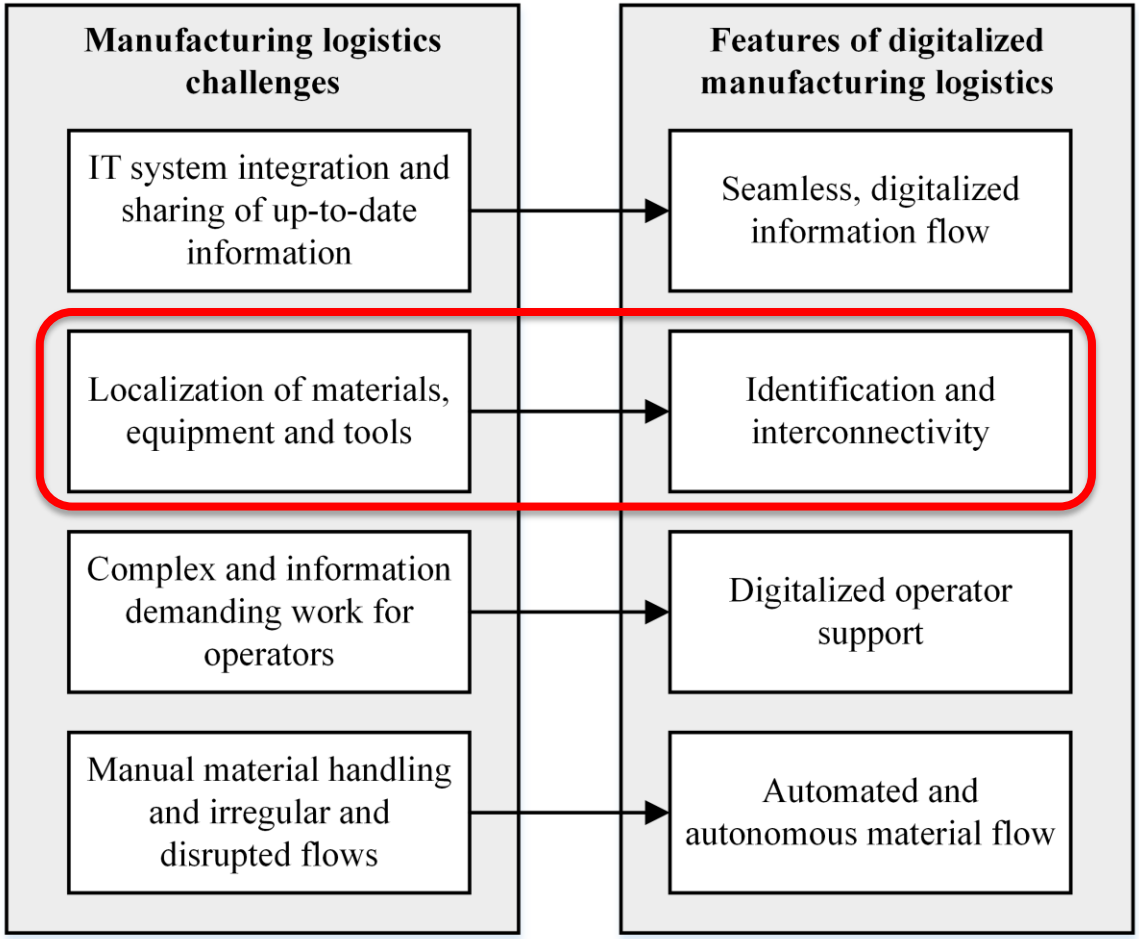


Features of digitalized manufacturing logistics in ETO



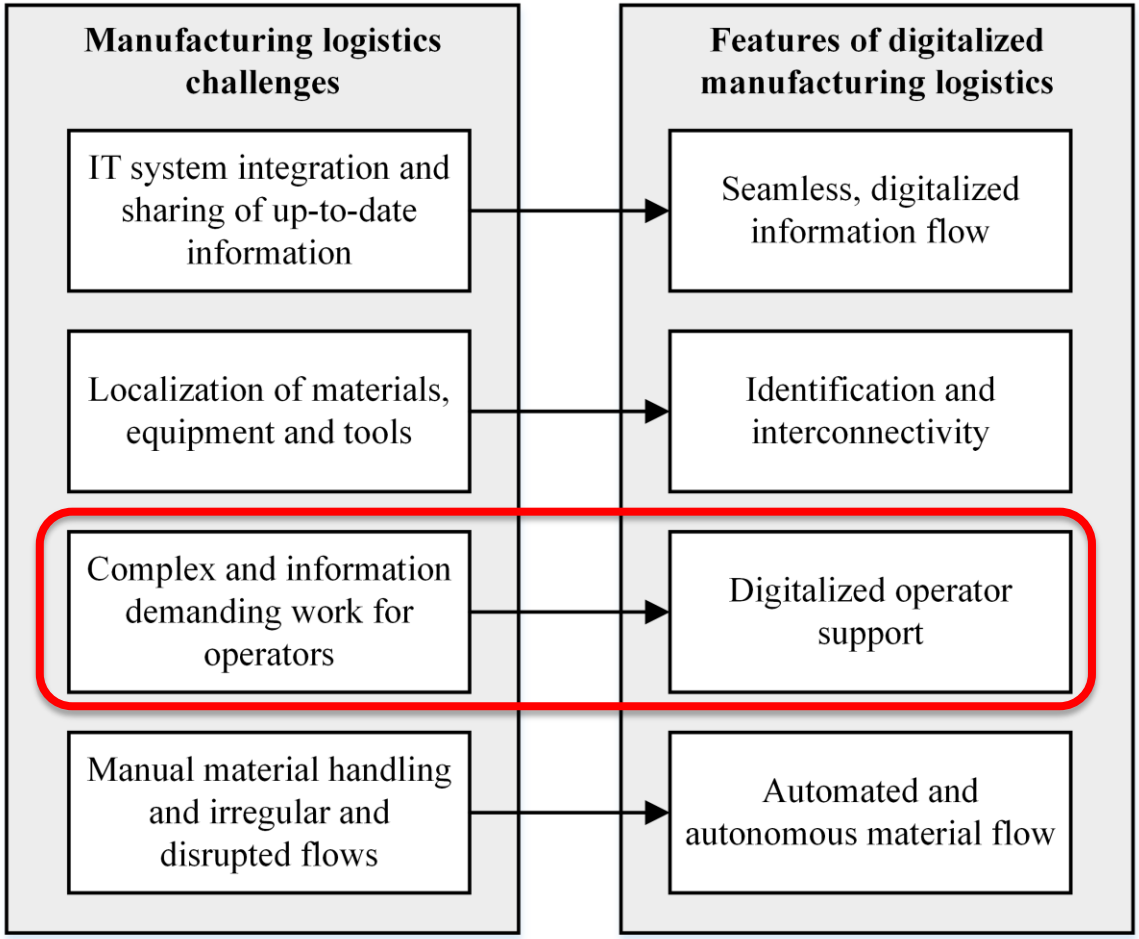
- The close integration between engineering and production in ETO manufacturing requires integrated IT systems for the efficient control and execution of manufacturing logistics activities.
- Necessary to provide operators with updated product drawings and models.
- With these challenges, there is a need for a seamless, digitalized information flow, where all subsystems are integrated.
- Information should flow continuously from the production floor to higher-level IT systems, giving access to real-time information

Features of digitalized manufacturing logistics in ETO



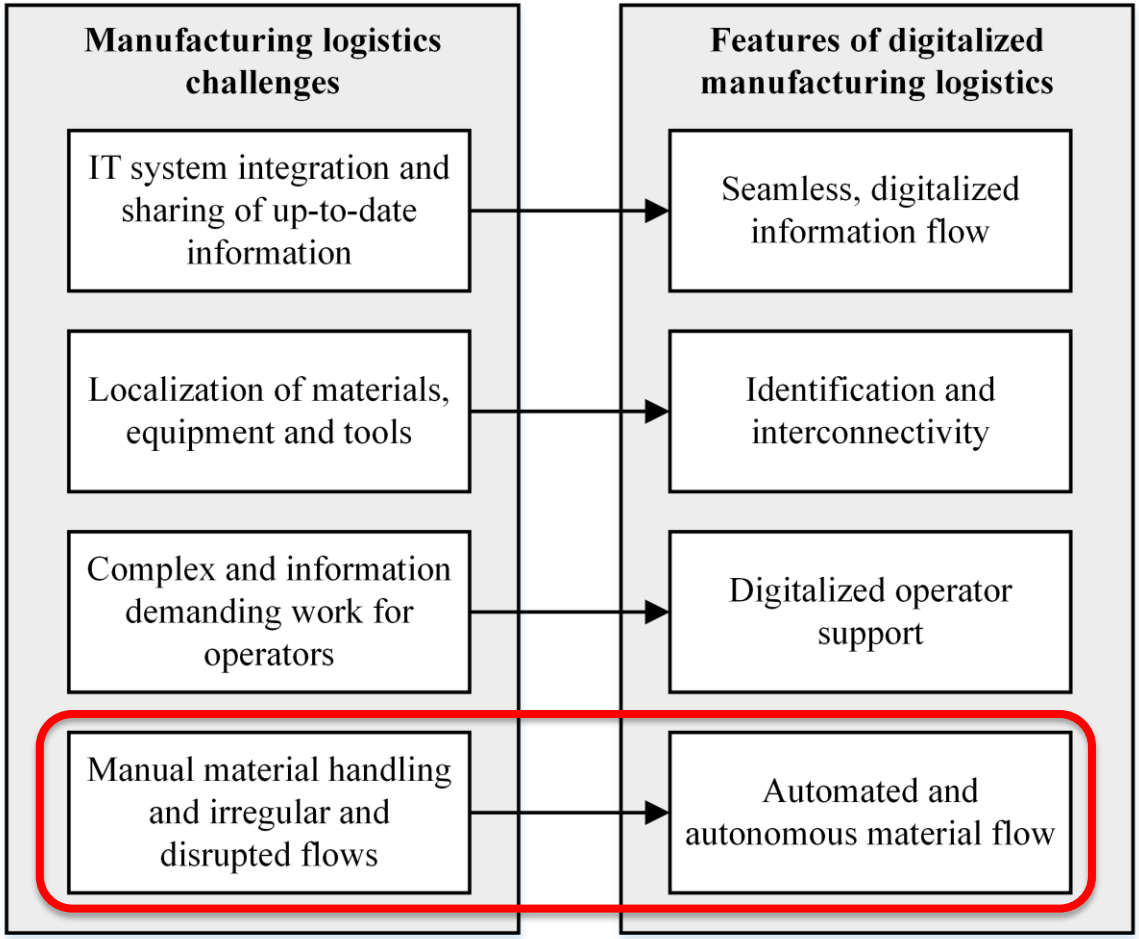
- Challenging to maintain an overview of all materials, equipment and tools necessary to perform operations.
- These challenges of localization of materials, equipment and tools requires that Identification and interconnectivity is provided through digital technologies.
- Identifying and interconnecting objects in a facility through the utilization of new technology will enable a highly integrated way of managing operations.

Features of digitalized manufacturing logistics in ETO



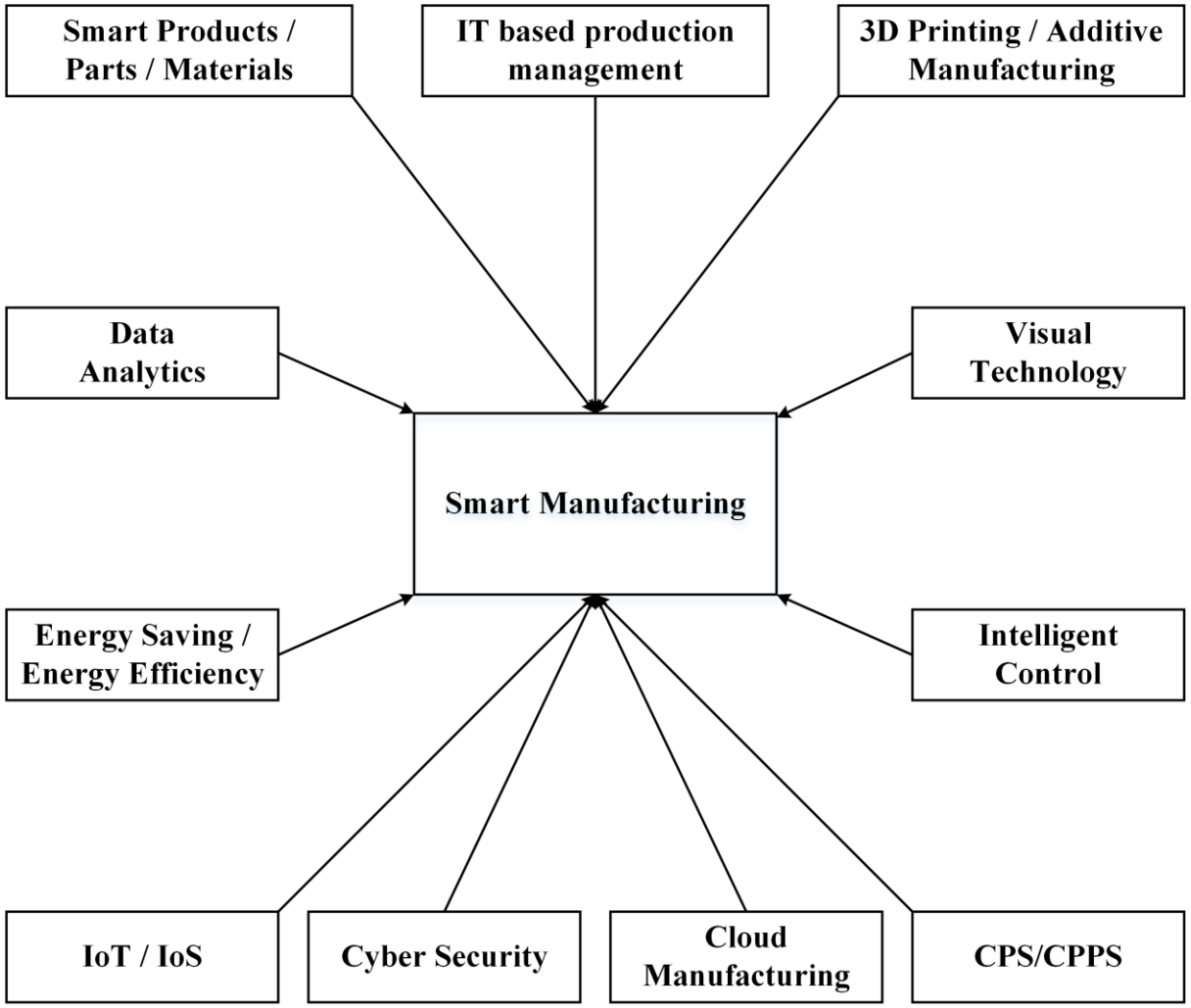
- Information about products, assemblies, processes etc. are critical for the operators to be able to perform the scheduled tasks and activities.
- Digitalized manufacturing logistics should therefore include digitalized operator support.
- Digital technologies should be utilized to provide enhanced support, giving rapid and easy access to required and up-to-date information about the processes and activities.

Features of digitalized manufacturing logistics in ETO



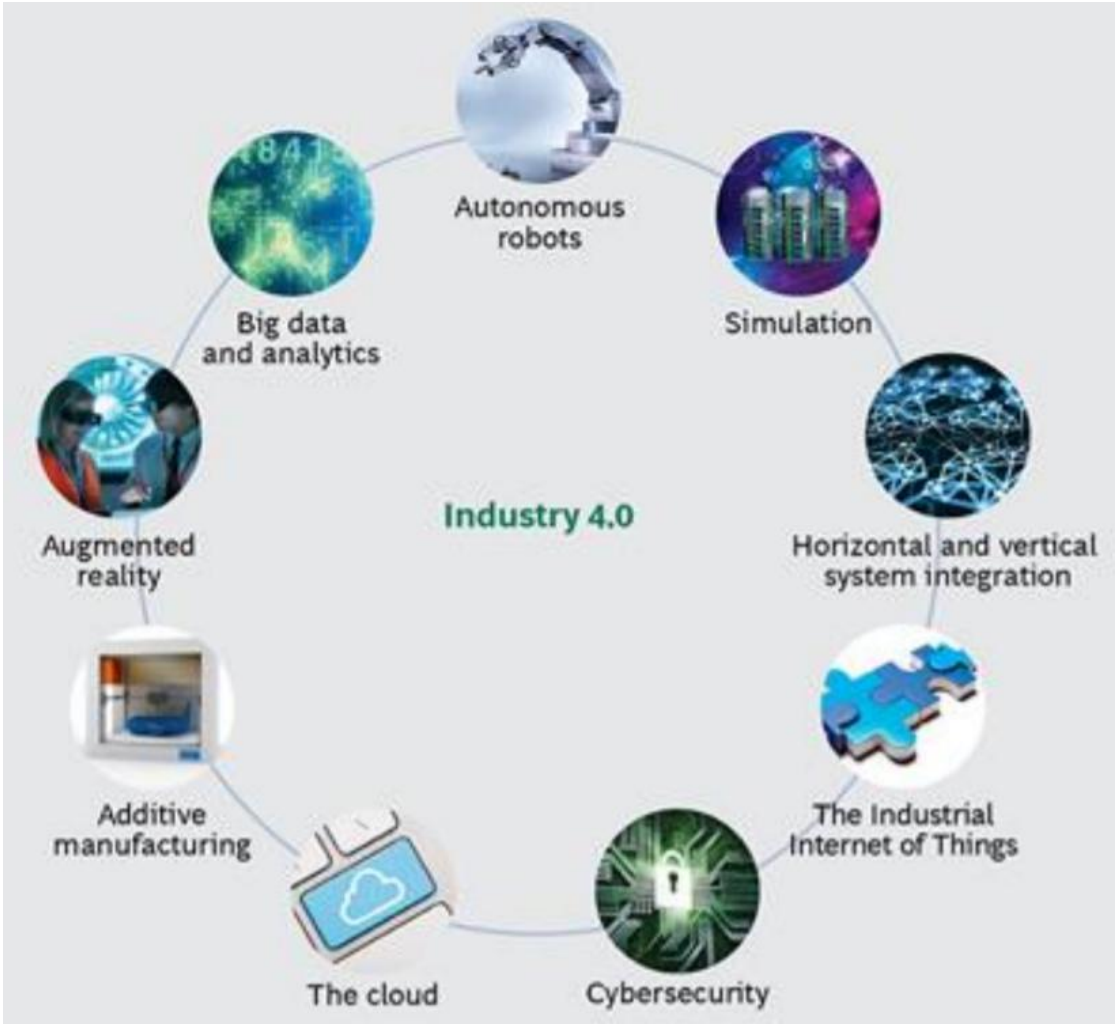
- With the manual material handling and irregular and disrupted material flow, there is a need for a more Automated and autonomous material flow.
- Products, components, tools, equipment and other objects can then be transported more efficiently, and with less human intervention.
- In manufacturing logistics, digital technologies can bring autonomy and automation to the physical flow of materials.

11 Technologies of «Smart Manufacturing»



Adapted from Mittal et al., (2017)

Nine technologies of Industry 4.0



(Rüssmann et al., 2015)

RFID for tracking and locating parts

(a) Precast storage yard

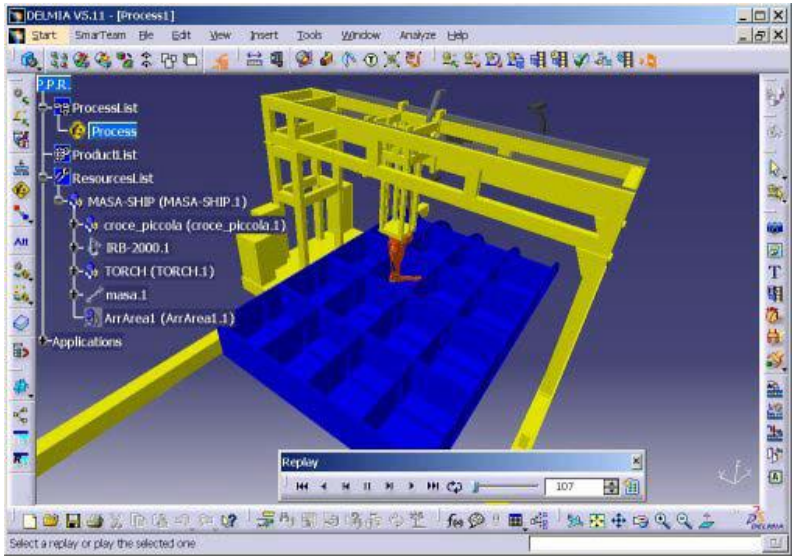
(b) Precast shipping trailer

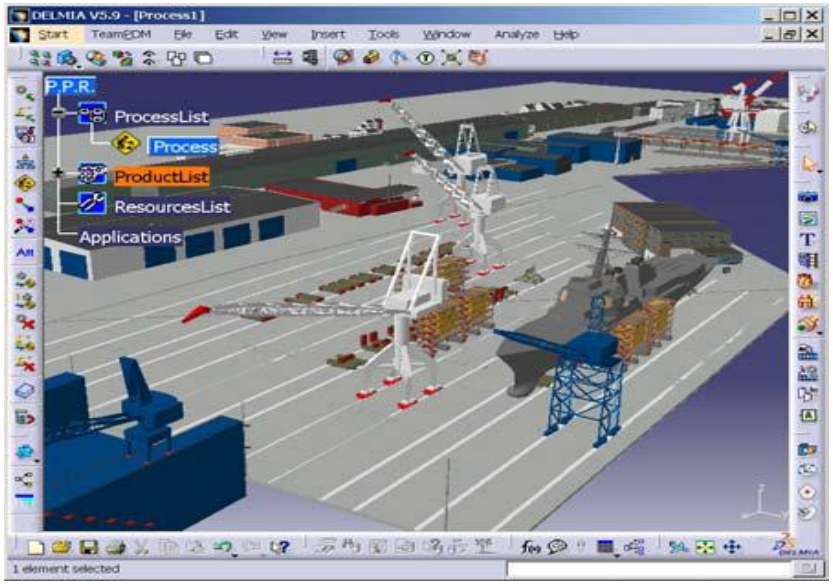
(c) Pipe spool shipping trailer

(d) Fire valves in a facility

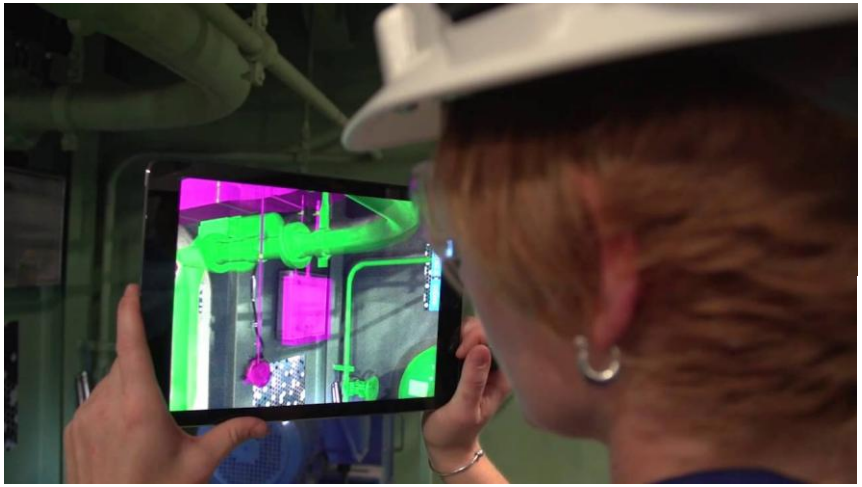
Technology

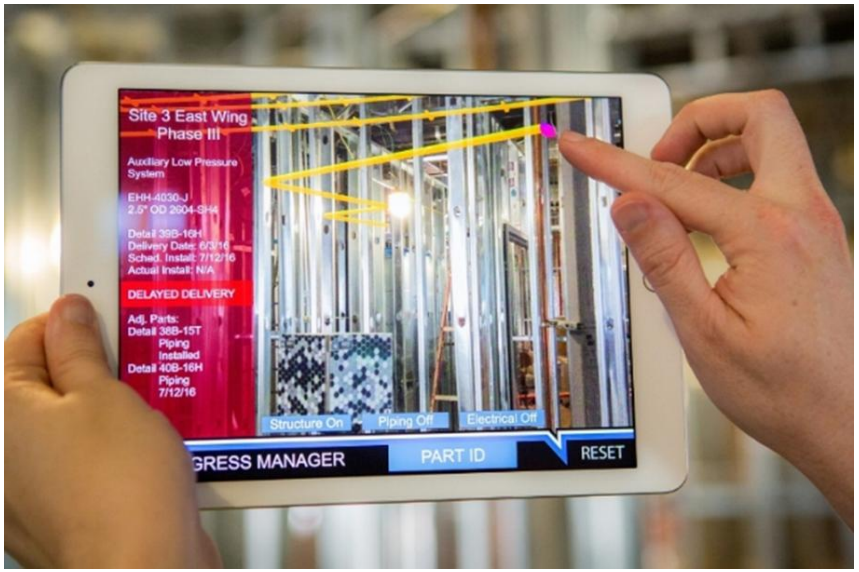
Shipbuilding simulations and digital twins

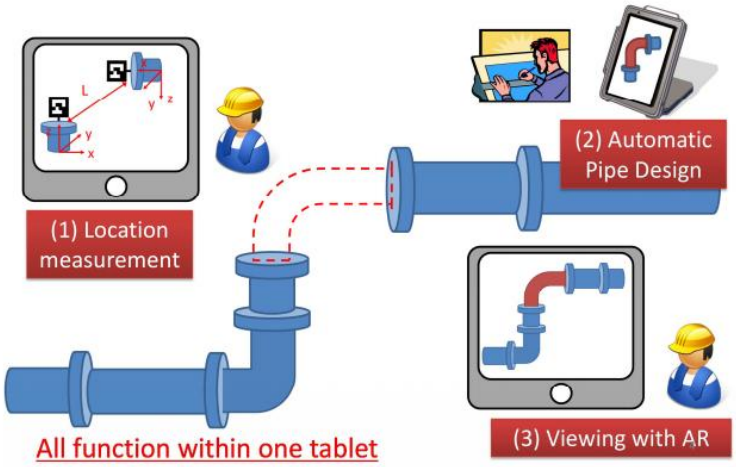




Augmented reality (AR) for outfitting support







Plant and process information sharing

- shipyard operators usually rely on paper to identify assets (e.g, pipes, machines, pallets) and determine which action should be performed according to the work orders.
- An AR application can suppress the vast majority of the paperwork by providing dynamic real-time information about the assets.
- Example:
  - information about the characteristics of a pipe shown on a smartphone.
  - contextual information like material, size and destination of each individual pipe

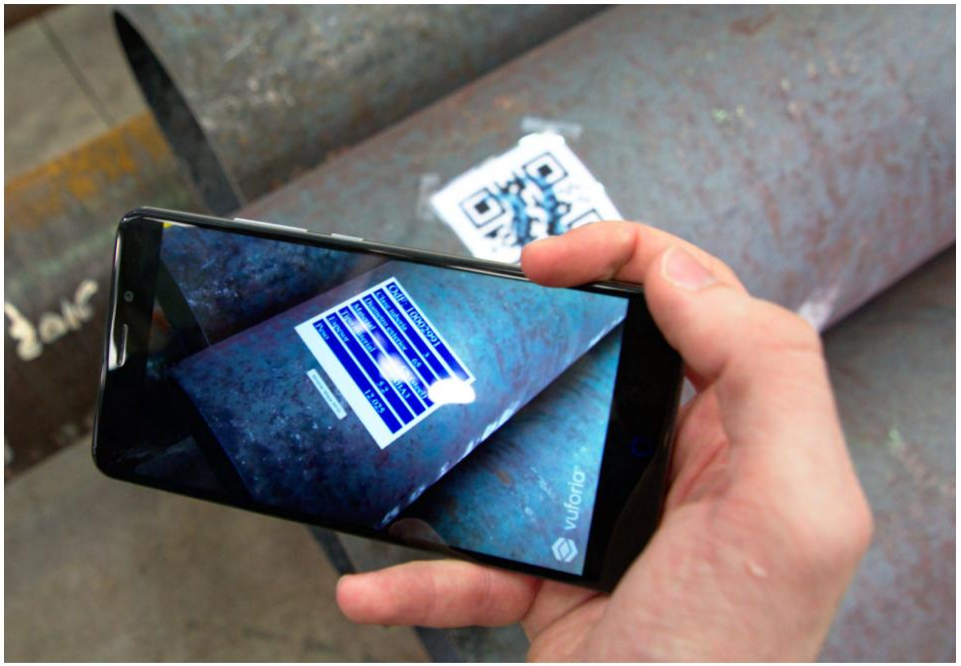


FIGURE 1. **Pipe information on a smartphone.**

(Blanco-Novoa, 2018)

Asset location

- a workshop context: large environment where assets can be anywhere.
- AR solutions can help to locate them by pointing at the specific place or area where an asset is.
- Example:
  - pipe location system based on active UHF RFID tags
  - The pipe location system can interact with an AR application in order to show such locations in portable devices like tablets or smart glasses

FIGURE 2. Localization of pipes using both IAR and an RFID-based system.

Visualization of installations

- in a ship it is usual that part of the infrastructure (i.e., piping, wiring) is installed behind bulkheads, roofs or ceilings, which makes its location difficult.
- AR can overlap the 3D design to reality and then show such a location.
- Monitor the shipyard infrastructure,
  - can even be linked to IoT data to show relevant notifications and variables in real time.
- Example:
  - the monitoring view of a shipyard when displayed through Microsoft HoloLens glasses in an office

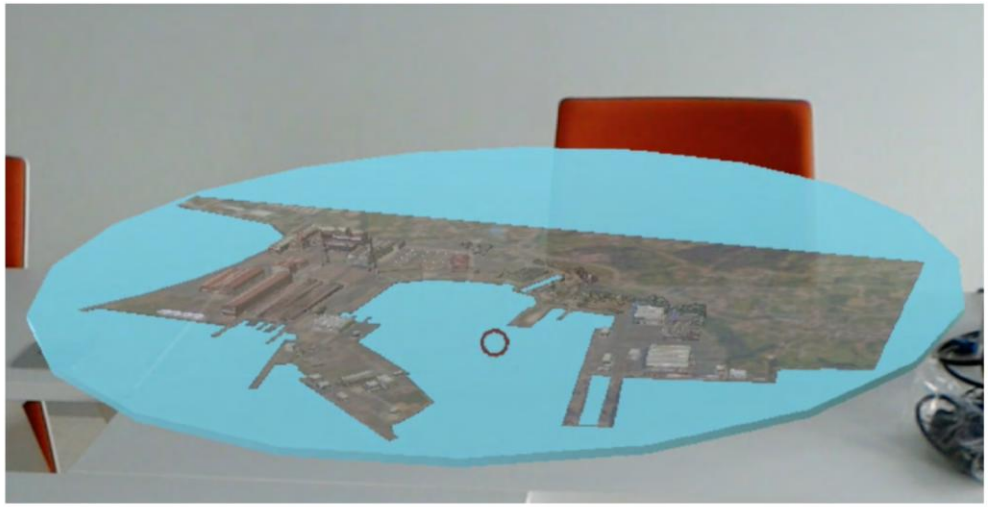


FIGURE 3. Shipyard model through HoloLens.

Warehouse management

- Provide operators with an AR-based guidance system that allows them to locate and store items faster and to decrease collection and storing errors.

- Example:
  - An AR application might show the content of the different shelves when looking for specific parts

FIGURE 4. Content of one of the shelves of a warehouse.

(Blanco-Novoa, 2018)

(Fernández-Caramés, 2018)

lication.

Figure 6. One of the tests in the pipe workshop with the HoloLens augmented collaboration application.

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