# ROBOTS AT THE CONSTRUCTION SITE

## An adjusted business model for construction companies

**Graduation research**

Master
Management in the Built Environment

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# CONTENT

A. Research proposal
B. Literature study
C. Methodology
D. Practice
E. Synthese & Design
F. Conclusions

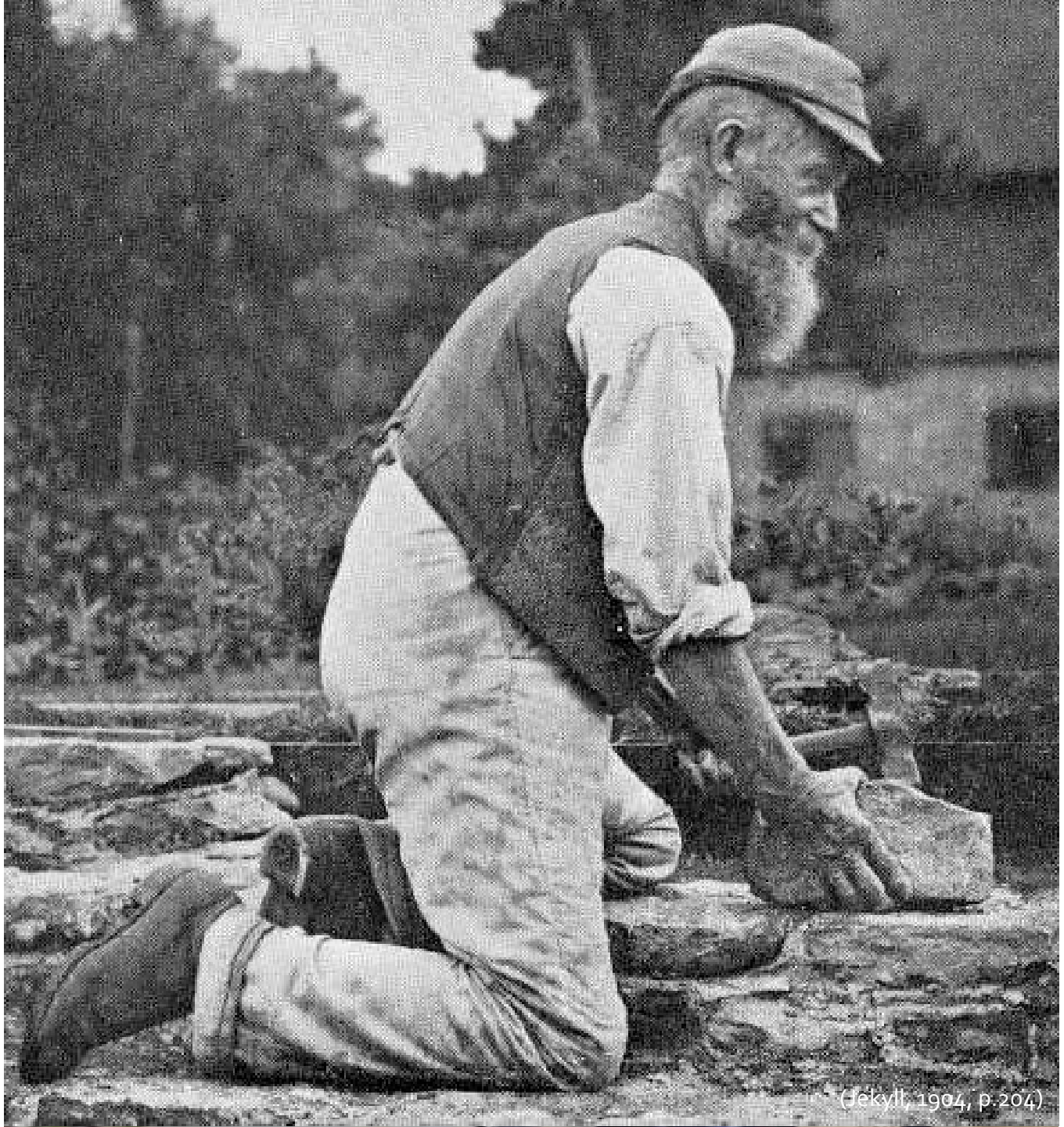
# A

## RESEARCH PROPOSAL

# STATUS OF THE INDUSTRY

The construction industry:

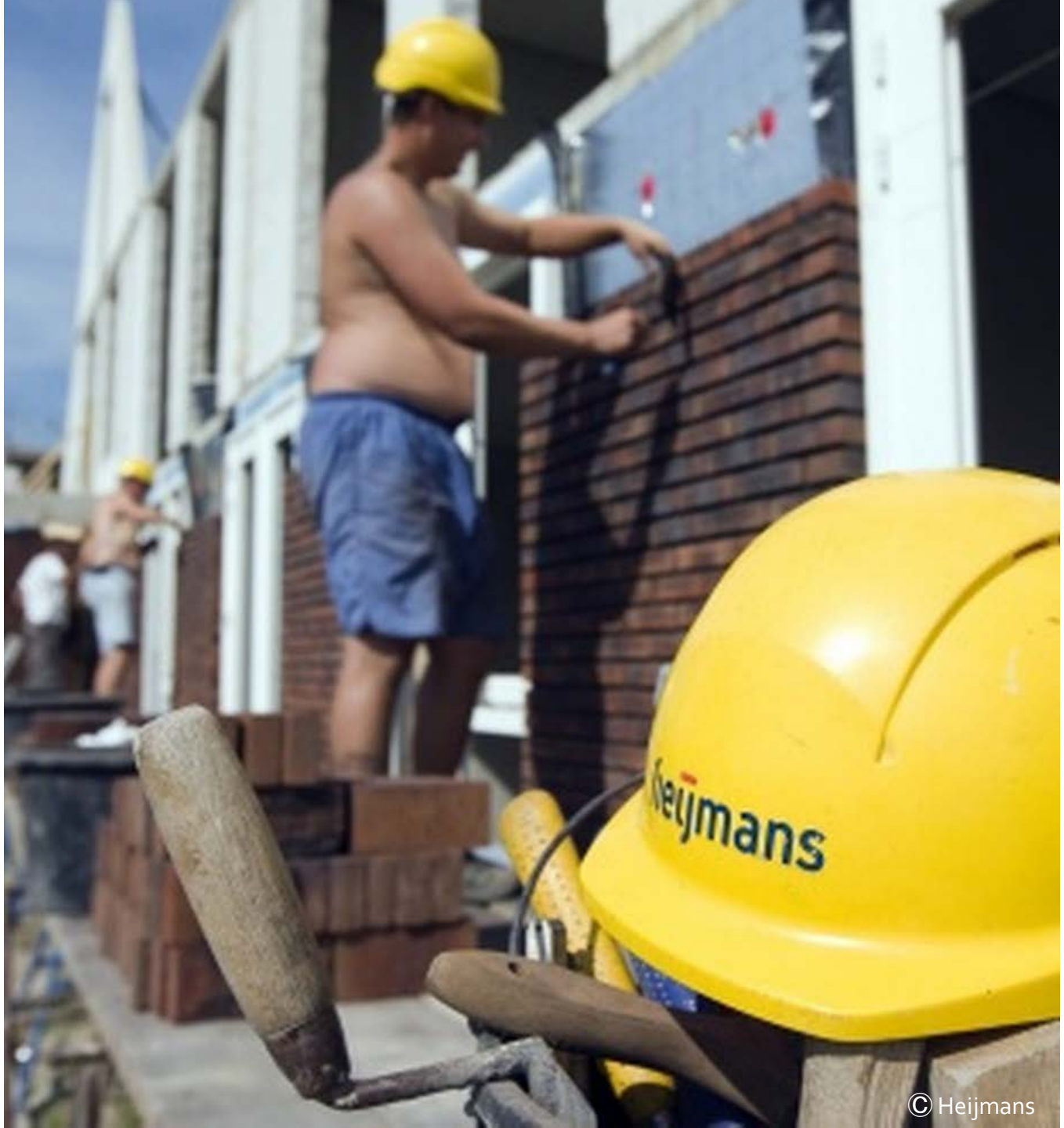
- One of the oldest professions
- Largest economic sector
  - 9,6 – 11,4 % GDP (Deloitte, 2016)
- Conservative and traditional
  - Methods have harldy changed



(Jekyll, 1904, p.204)

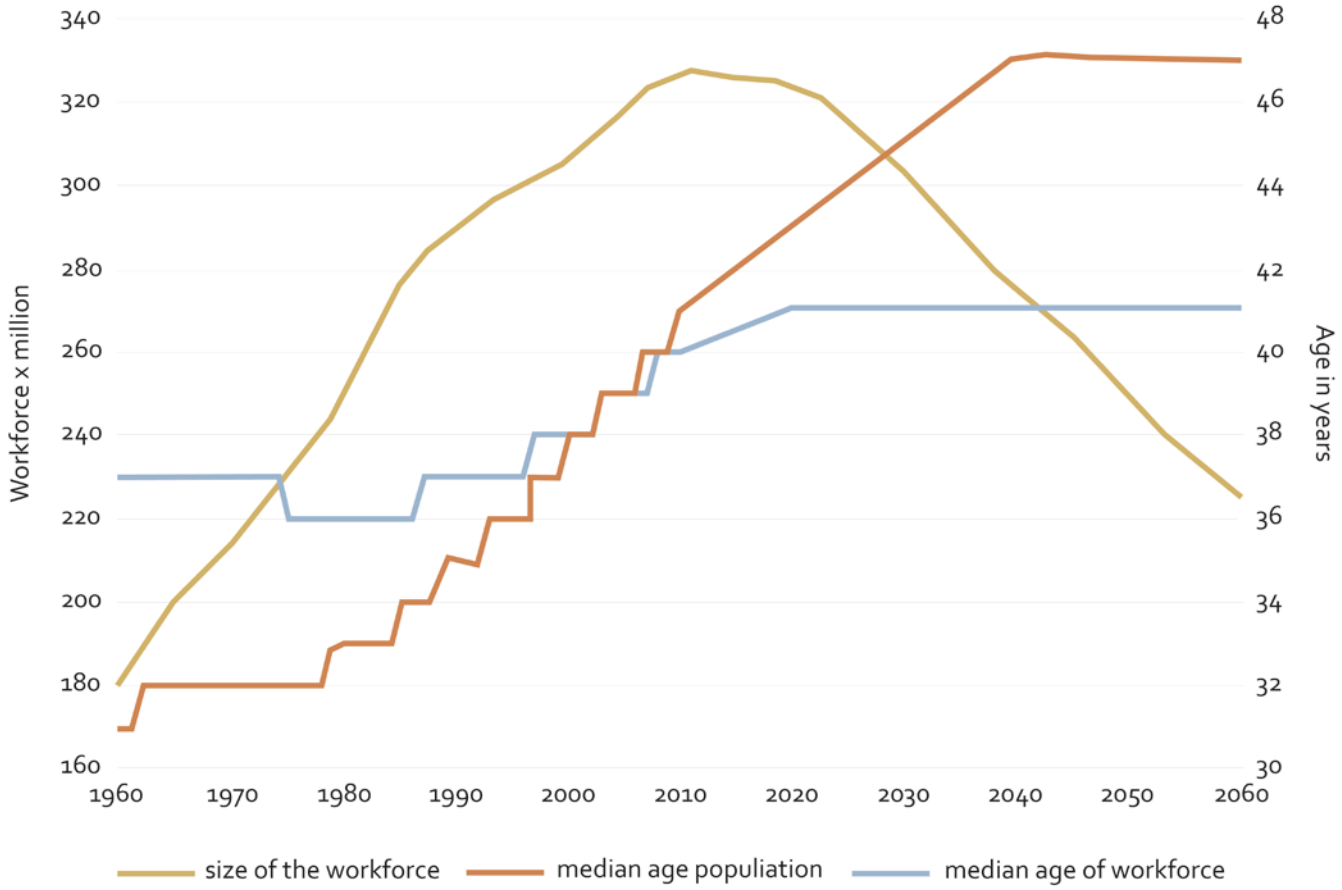
# STATUS OF THE INDUSTRY

- Unfamiliar with R&D of robotics and automation
- Difficult due to
  - Unstructured work
  - Heavy objects
  - Low level of standardistation
  - Medium level of prefabrication
  - Nummerous involved actors



# NEED FOR CHANGE

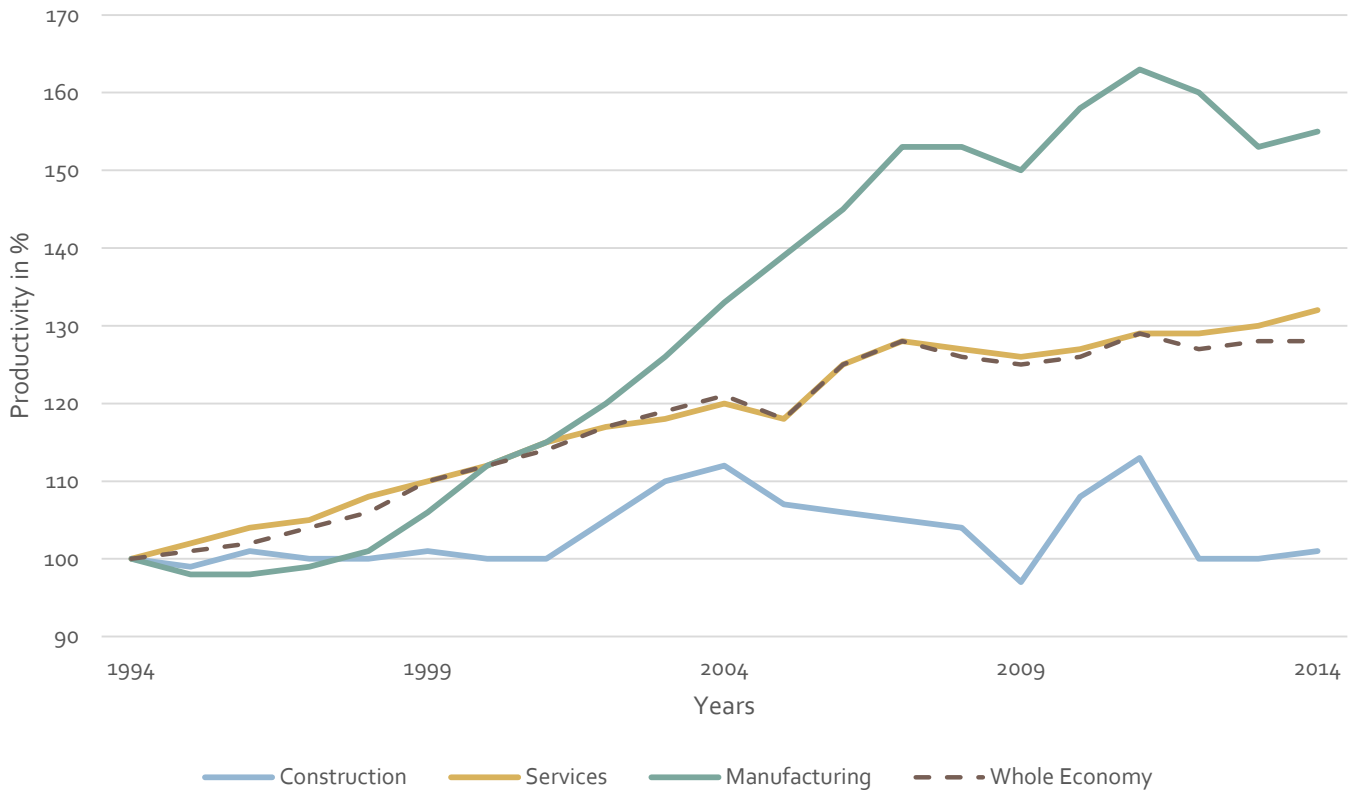
- Increasing real estate demand
  - Urbanisation
- Lack of workforces
  - Recession
  - Dangerous & unhealthy
  - Aging of world's population




(Gassel, 2010, p. 73)

# NEED FOR CHANGE

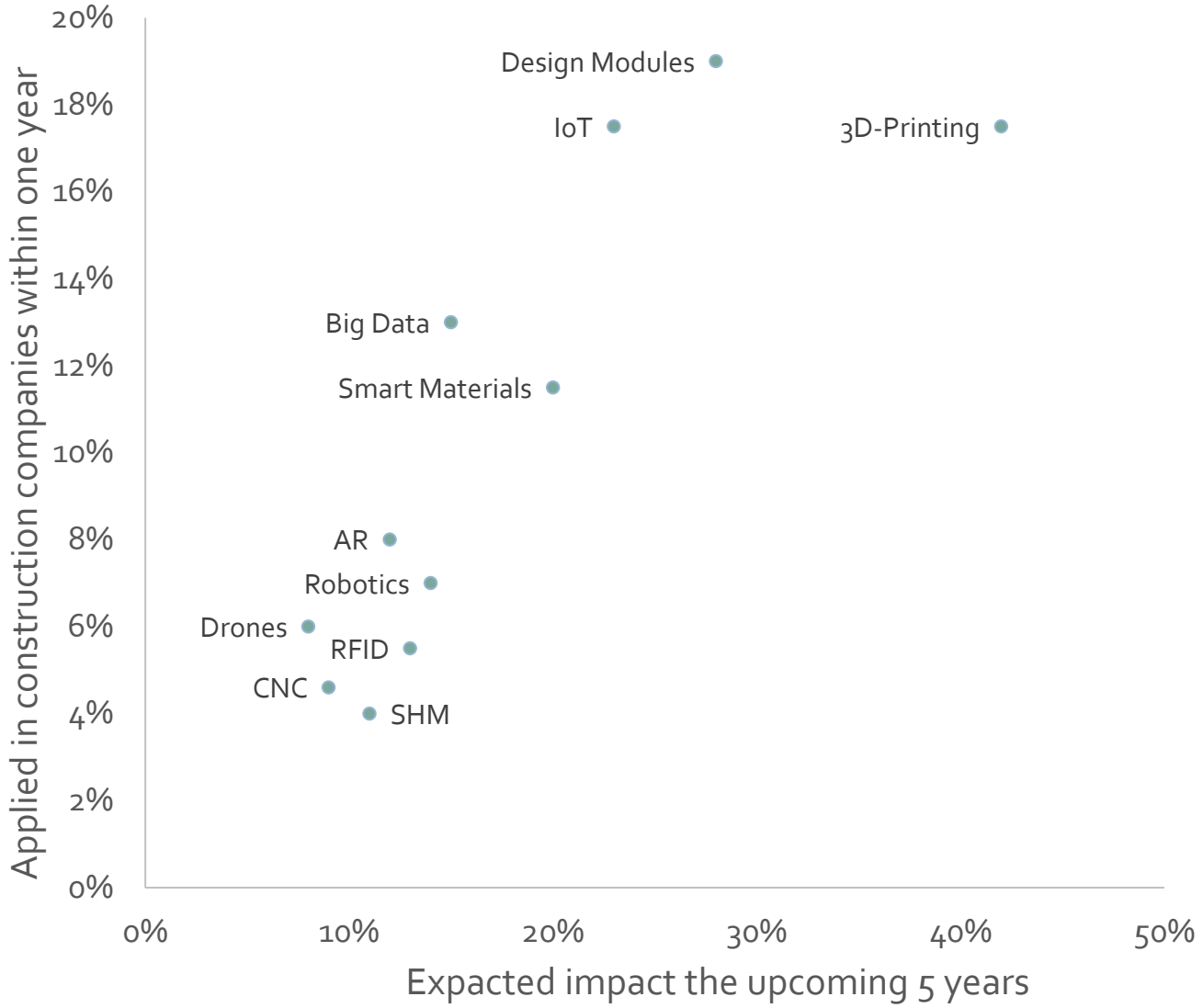
- Increasing real estate demand
  - Urbanisation
- Lack of workforces
  - Recession
  - Dangerous & unhealthy
  - Aging of world's population
- Low productivity




(The Chartered Institute of Building, 2016)

# POTENTIAL TECHNOLOGICAL TRENDS

- R&D start focusing on automation and robots
  - Construction phase:
    - Robotics
    - Drones
    - 3D printers
- Proven technologies in other industries




(Bouwkennis, 2016)

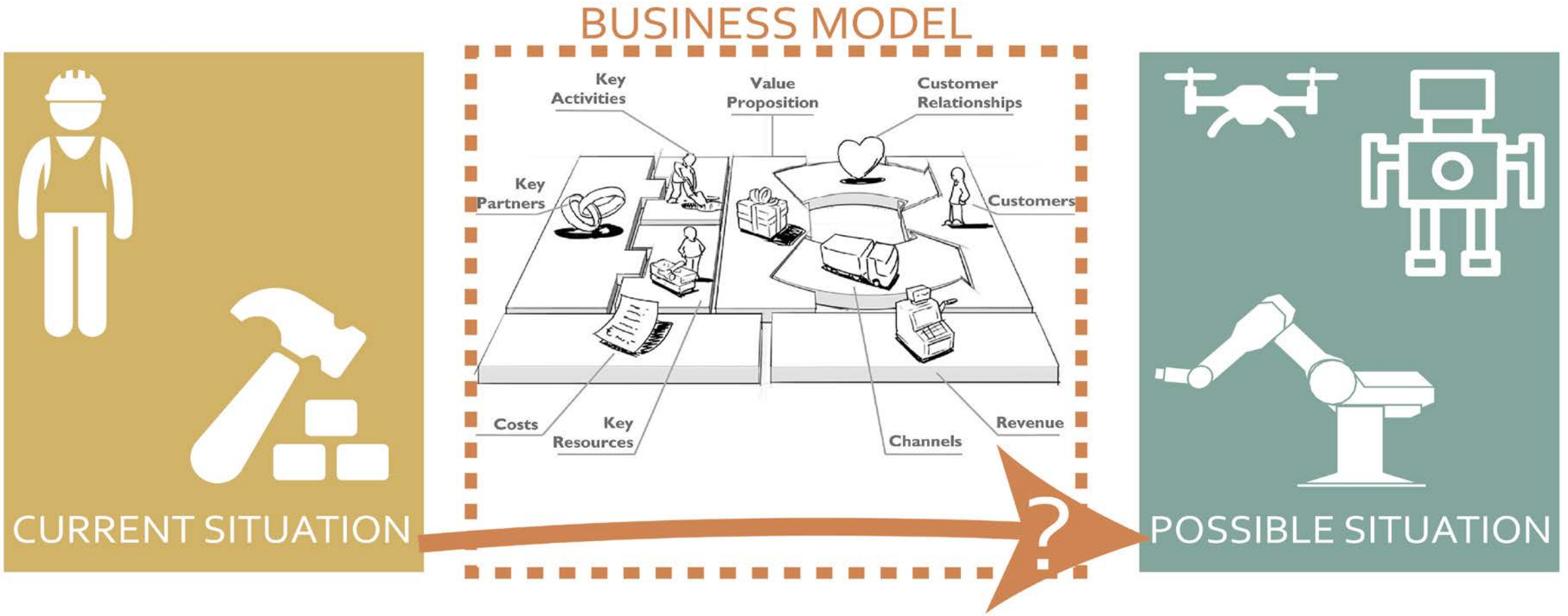
# PROBLEM ANALYSIS

Innovation is possible when

- Need-based feasibility
  - Will increase over the years
- Technical feasibility
  - Technology is proven
- Economic feasibility
  - Must be proven

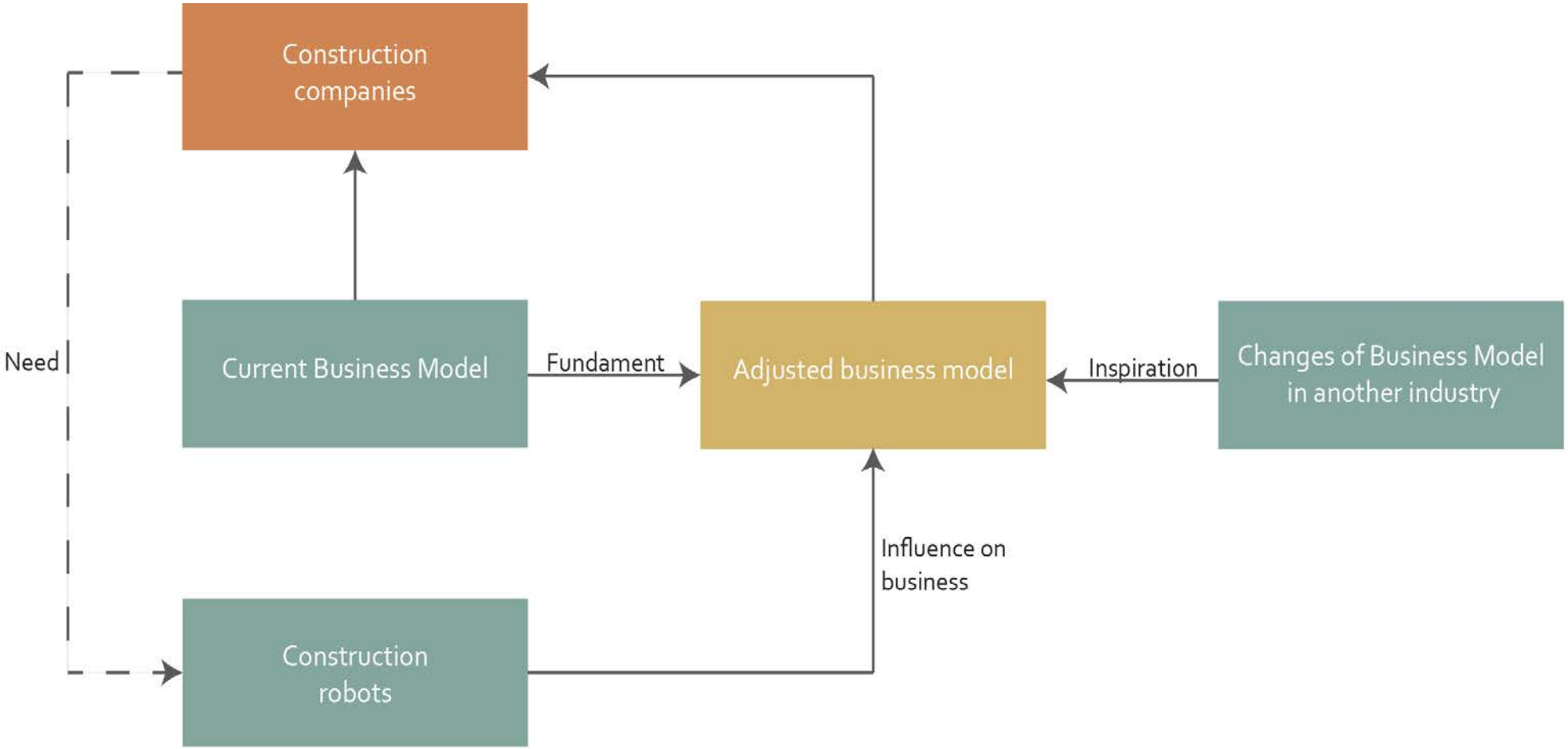
*'Technology by itself has no single objective value. The economic value of technology remains latent until it is commercialized in some way via a business model'*
– Chesbrough (2010)

# PROBLEM STATEMENT



# RESEARCH QUESTION

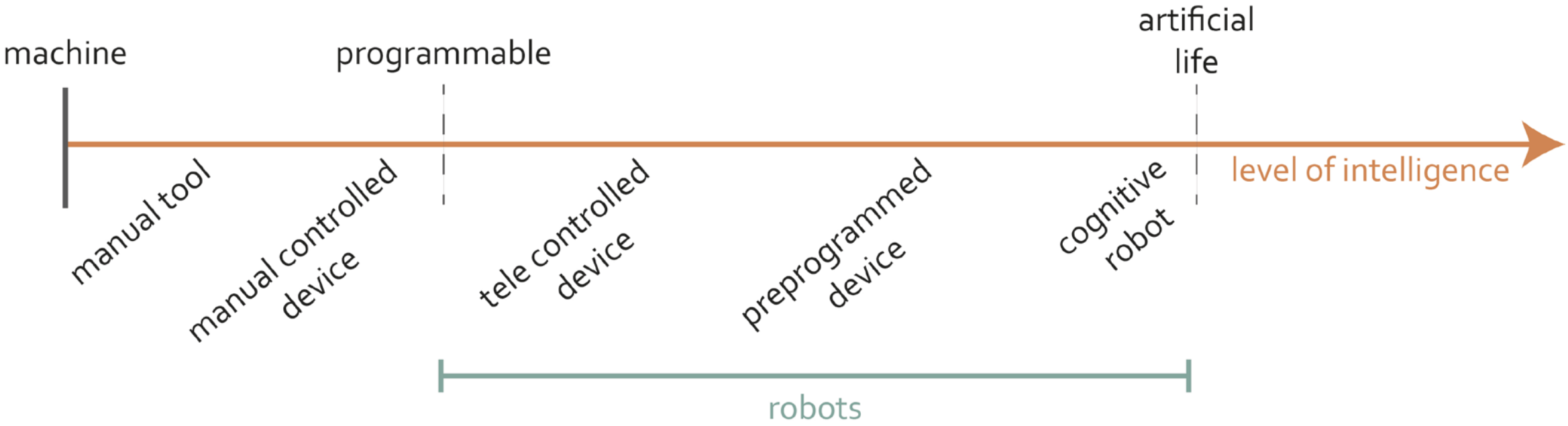
How can **Dutch construction companies** adjust their **business model** in order to make **robots** at the **construction site** possible?



# B

# LITERATURE STUDY

# DEFINITION OF A ROBOT



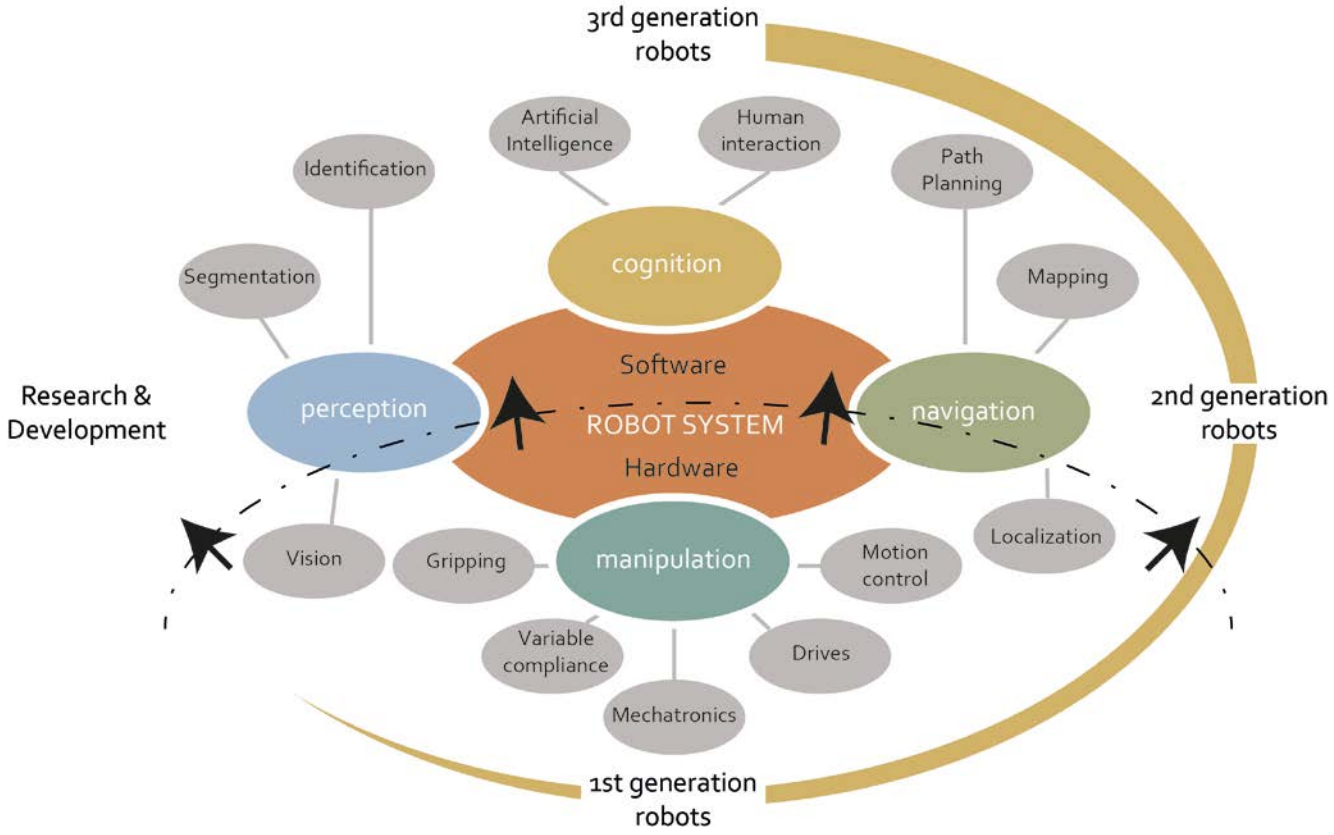

- No consensus about the definition.
- *A robot is a smart, multitasking machine, controlled by a computer which is attached to a movable physical body, which (semi) automatically performs jobs and can react to its environment based on given data, calculations and own observations.*

(van Gassel, 1999; Rouwenhorst, 2016)

# STATE OF THE ART

Robot = Hardware + Software

- 1st Generation
  - Focus: Manupulation
- 2nd Generation robots
  - Focus: Perception & Navigation

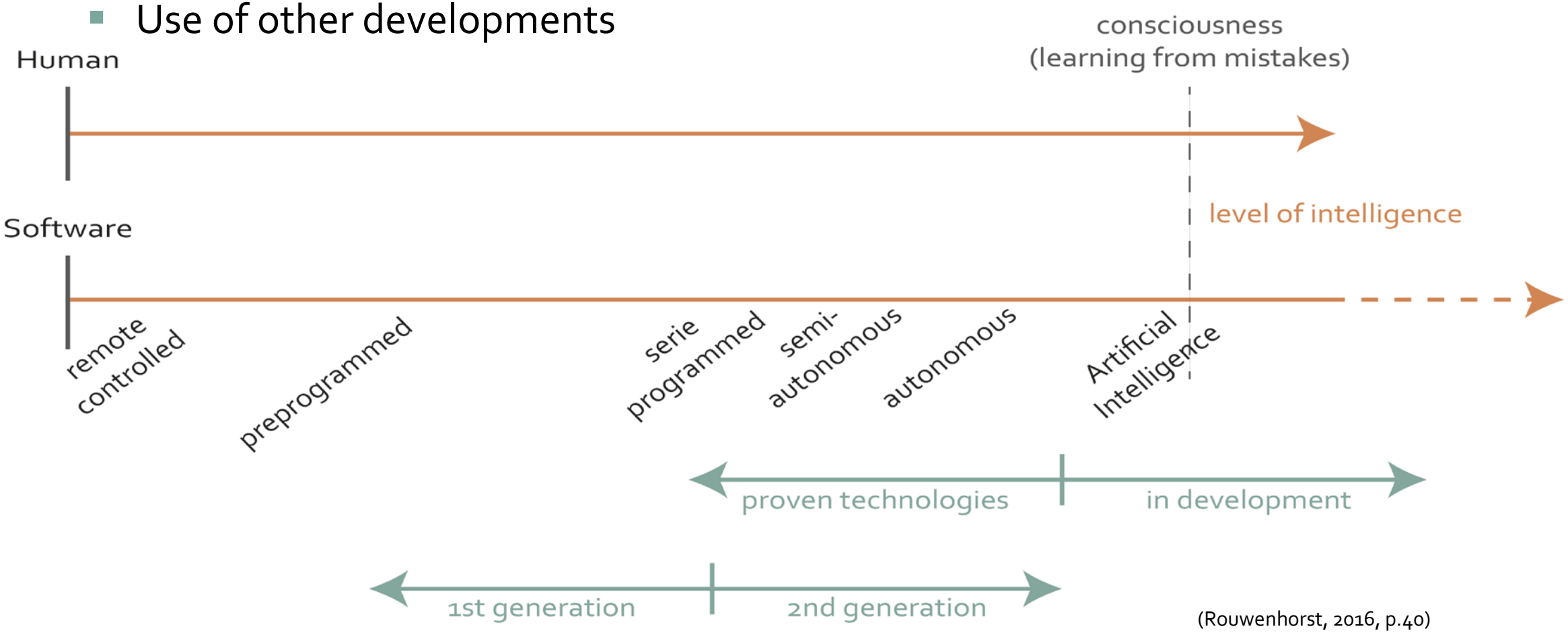



(Brabantse Ontwikkelings Maatschappij, 2015, p.26)

# STATE OF THE ART

Software

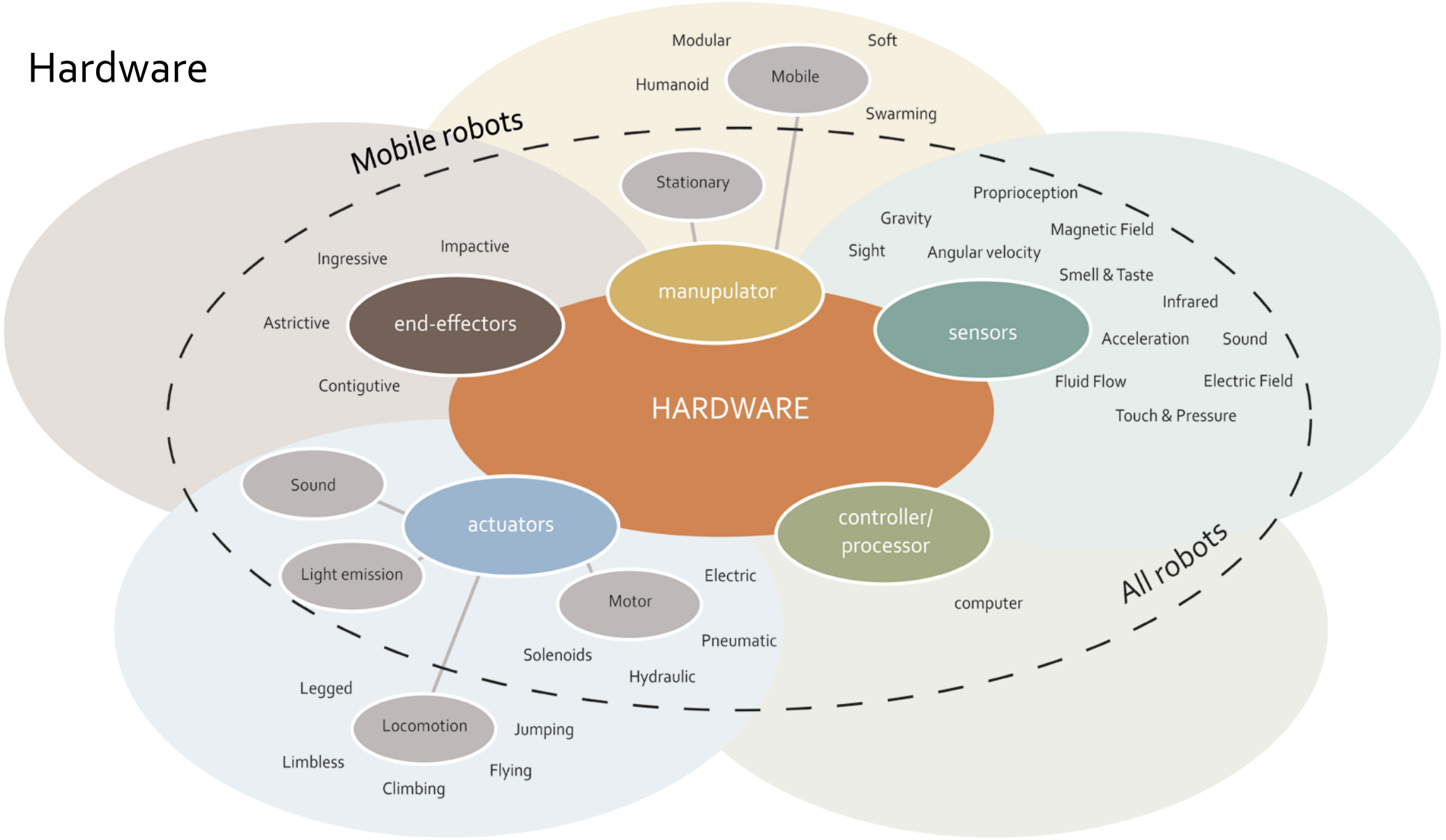
- Vision systems
- Navigation and perceptions
- Use of other developments




(Rouwenhorst, 2016, p.40)

# STATE OF THE ART

## Hardware



# STATE OF THE ART

Construction robots

- Limited robots developed for construction
- Second-generation robots
  - Heavy, repetitive work in an accurate way
  - Relatively simple  singular tasks
  - Impossible in unstructured environments

# EMPLOYABILITY OF ROBOTS

Off-site robots

- Industrial manufacturing robots for prefabrication
  - Highly accurate production
  - Completely finished (Piping, wiring, sockets)

(Heidinga, 2015)

# EMPLOYABILITY OF ROBOTS



## On-site robots

- 200 on-site robots developed
- Only a few robots for sale
- Hardly applied in the Netherlands

| Construction tasks |
| --- |
| Assembly |
| Building skeleton erection |
| Coating of fire protection on steel |
| Concrete distribution |
| Earthwork |
| Interior finishing (painting, plastering, tiling) |
| Lifting heavy elements |
| Masonry |
| Removal of old coating |
| Road paving |
| Surface finishing (concrete, tile-setting) |
| Welding |
| Window glass mounting |

(Bock, 2006; Bulusu, 2015; Elattar, 2008; Abderrahim & Balaguer, 2008)

# ADVANTAGEOUS

- Ensure production capacity and deal with the workforce shortages
- Improve productivity and efficiency
- Improvement of safety and health of construction workers
- Improve quality and accuracy of the buildings
- Shift to mass customization
- Increase sustainability

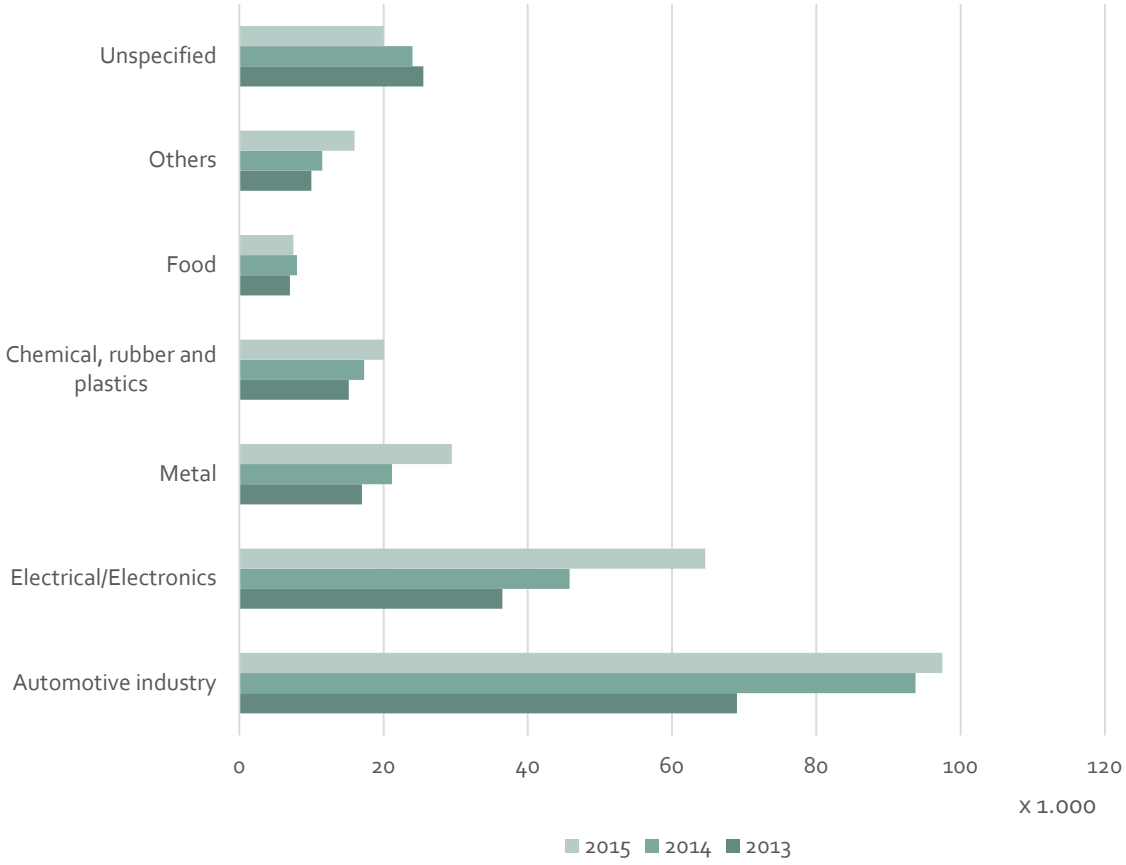
# CRITICAL POINTS OF ROBOTS

Critical points differ and are not corresponding

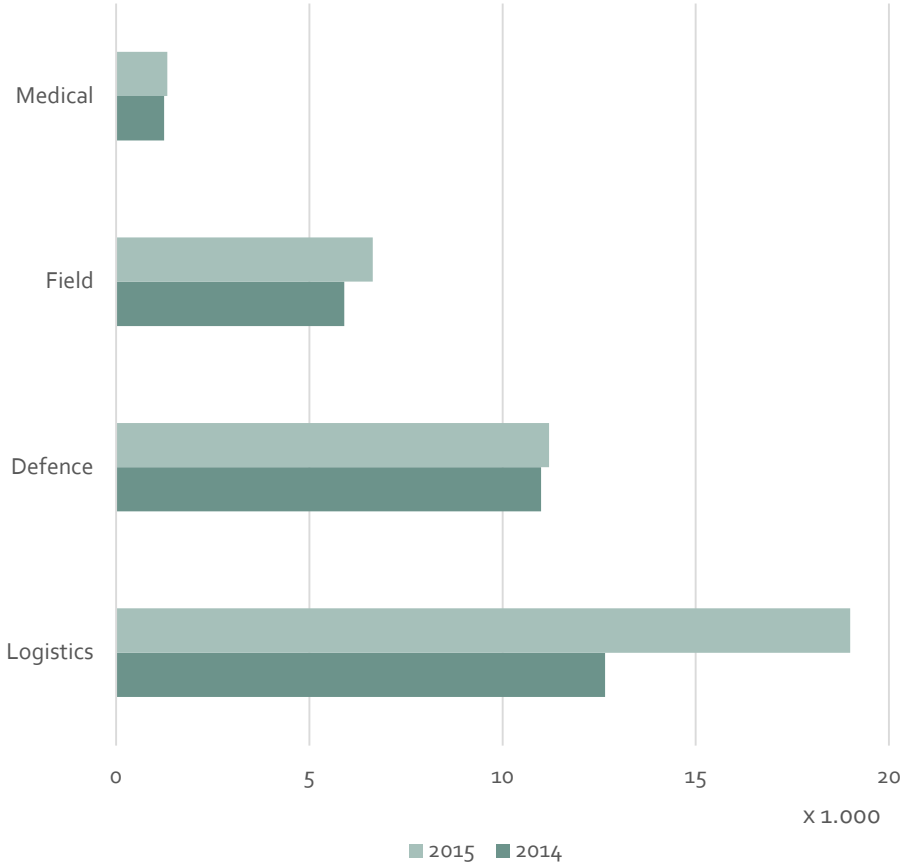
- Increasing unemployment
- Shift in jobs low educated to high educated employees
- Higher use of electricity and new occuring problems
- Liability is not established yet
- Lack of legislation can delay the construction process

# ROBOTIZED INDUSTRIES

## Industrial robots




## Service robots




(International Federation of Robots, 2016)

# INTRODUCTION

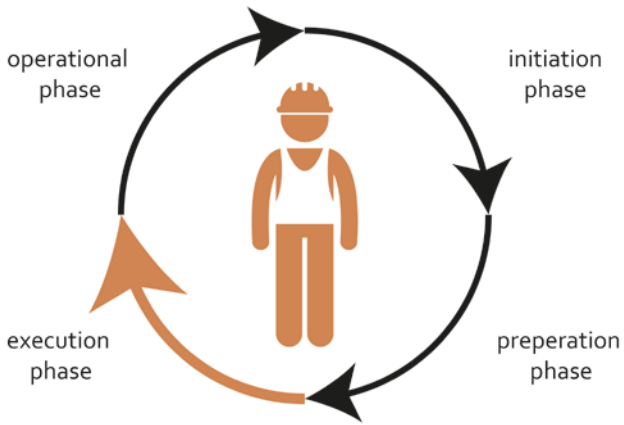
- 156.000 Dutch companies
- 80 % one-man businesses, mainly focused on one field
- Appr. 500 small companies are part of the 12 largest
- Large companies operate in multiple fields
- Seven out of ten companies are focusing on residential construction

| Companies | Revenue 2016 X 1.000.000 | Operating field |
|---|---|---|
| BAM | 7423 | Infra, RE, Residential |
| Volker Wessels | 4906 | Infra, RE, Residential, Installations |
| Boskalis | 3240 | Infra, Civil, Offshore, Maritime |
| Van Oord | 2579 | Civil, Offshore |
| Heijmans | 1979 | Infra, Civil, RE, Residential, Utility |
| Strukton | 1907 | Infra, Civil, RE, Installations |
| TBI | 1557 | Infra, Residential, Utility, Technique |
| Dura Vermeer | 1052 | Infra, RE, Residential, Utility |
| Ballast Nedam | 850 | Infra, RE, Residential, Utility |
| Van Wijnen | 693 | RE, Residential, Utility |

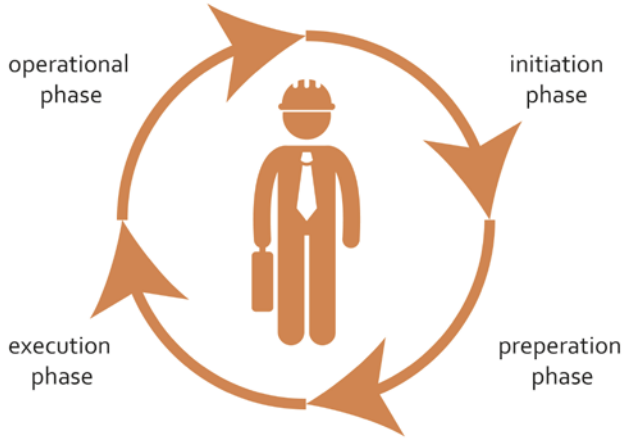
(Cobouw, 2016)

# CHANGING ROLE

- Traditionally active in execution phase
  - Construction tasks
- Shifted to construction management companies
  - Outsourcing activities
- More ground in the construction proces
  - Also developers
  - Integration of design and construction
  - To preserve own construction capacity



Traditional contractor



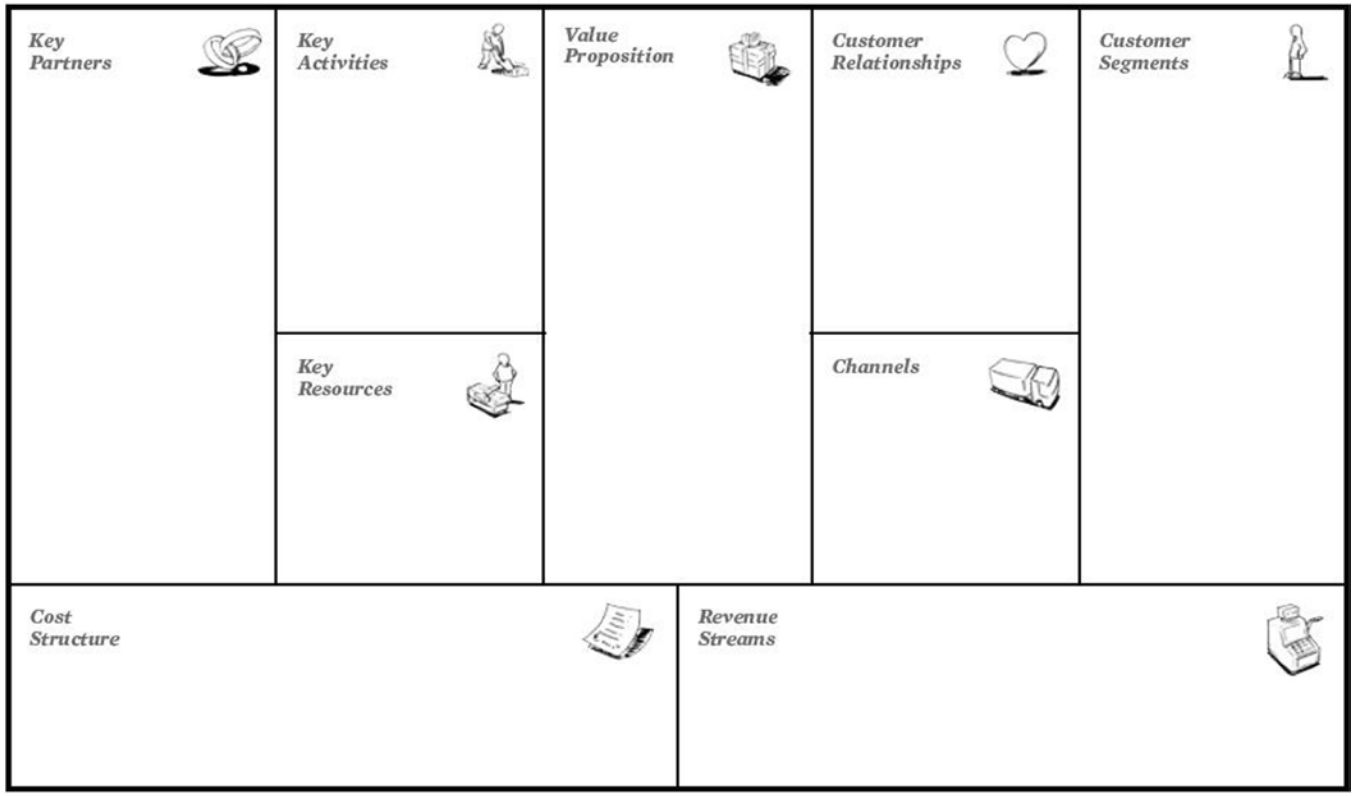
Contemporary contractor

# CONSTRUCTION METHODS

| | Casting | Masonry | Wooden skeleton | Prefab elements | Prefab units |
|---|---|---|---|---|---|
| Preparation time | Medium | Short | Long | Long | Long |
| Construction site | Big | Medium | Small | Small | Small |
| Construction time | Medium | Long | Short | Super Short | Super short |
| Consumer-oriented | Low | High | Low | Medium | Medium |
| Equipment cost | Super high | Low | Low | High | High |
| Finishing | High | Low | Low | High | Super high |
| Labour intensity | Low | Super High | Medium | Low | Very low |
| Scale of the project | Big | Small, variation | Small | Big | Big |
| Weather dependency | Super high | Medium | Low | Low | Low |

# DEFINITION

- No consensus
- Osterwalder and Pigneur (2010) will be used: '*A business model describes the rationale of how an organisation creates, delivers, and captures value'.*




(Osterwalder & Pigneur, 2010)

# BUSINESS MODEL OF CONSTRUCTION COMPANIES



- Project-based business
- No concensus about the level of the business model
- Neither about the definition and purpose of a BM
- 'Anything to Anyone business'
- No unique elements
- No generic business model

# C METHODOLOGY

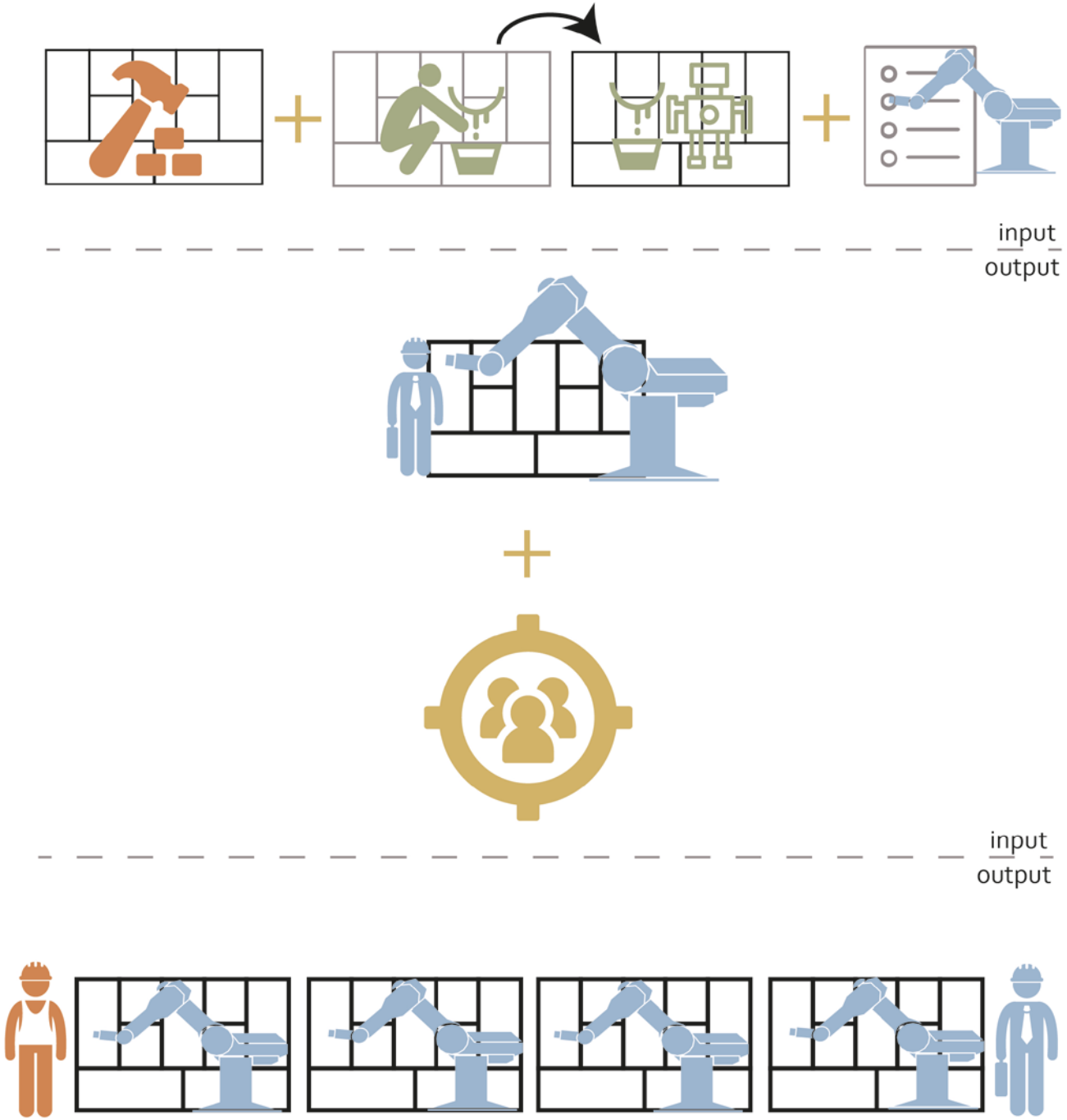
# RESEARCH METHODS

- Hybrid research
  - Empirical
  - Operational

- Literature review
- Explorative interviews
- Semi-structured interviews
  - Strategic level
- Focus group

- Selections
  - 3D concrete printing robot
  - 7 largest + 1 medium construction companies
  - Case study Dairy industry

- Framework
  - Business model canvas



# D

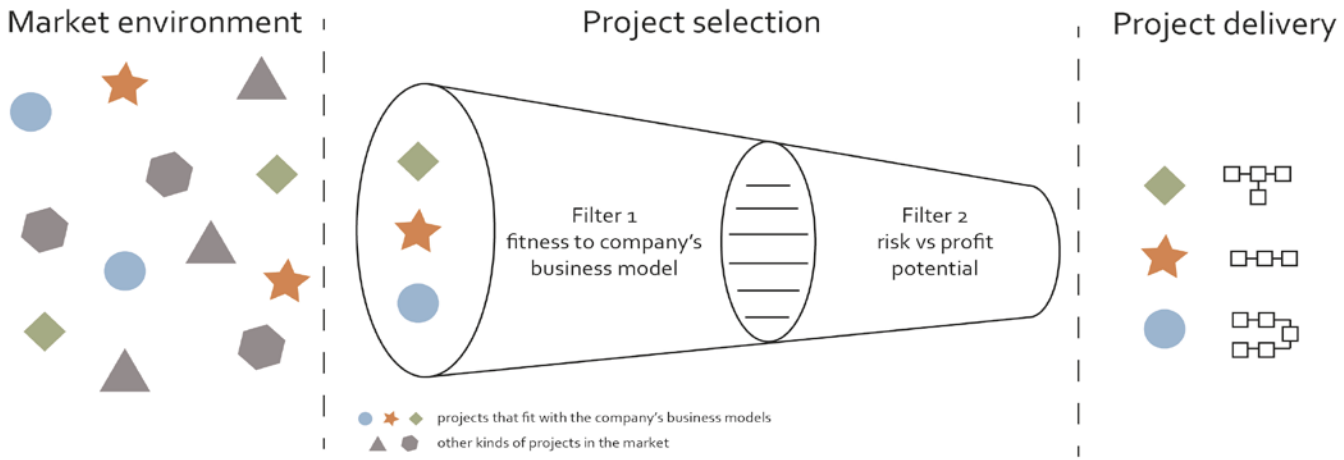
## PRACTICE

# DEFINITION

- Practice found it difficult to define business model
- About earnings & financial profitability (7/8)
  - *'The business model, is the way you earn money or?' – Interviewee Company 3*
- Complemented by
  - Value of the project of service
  - Explain how a company sustains
- One company which shows a implicit business model
- No corresponding internal definition (3/3)

# USE

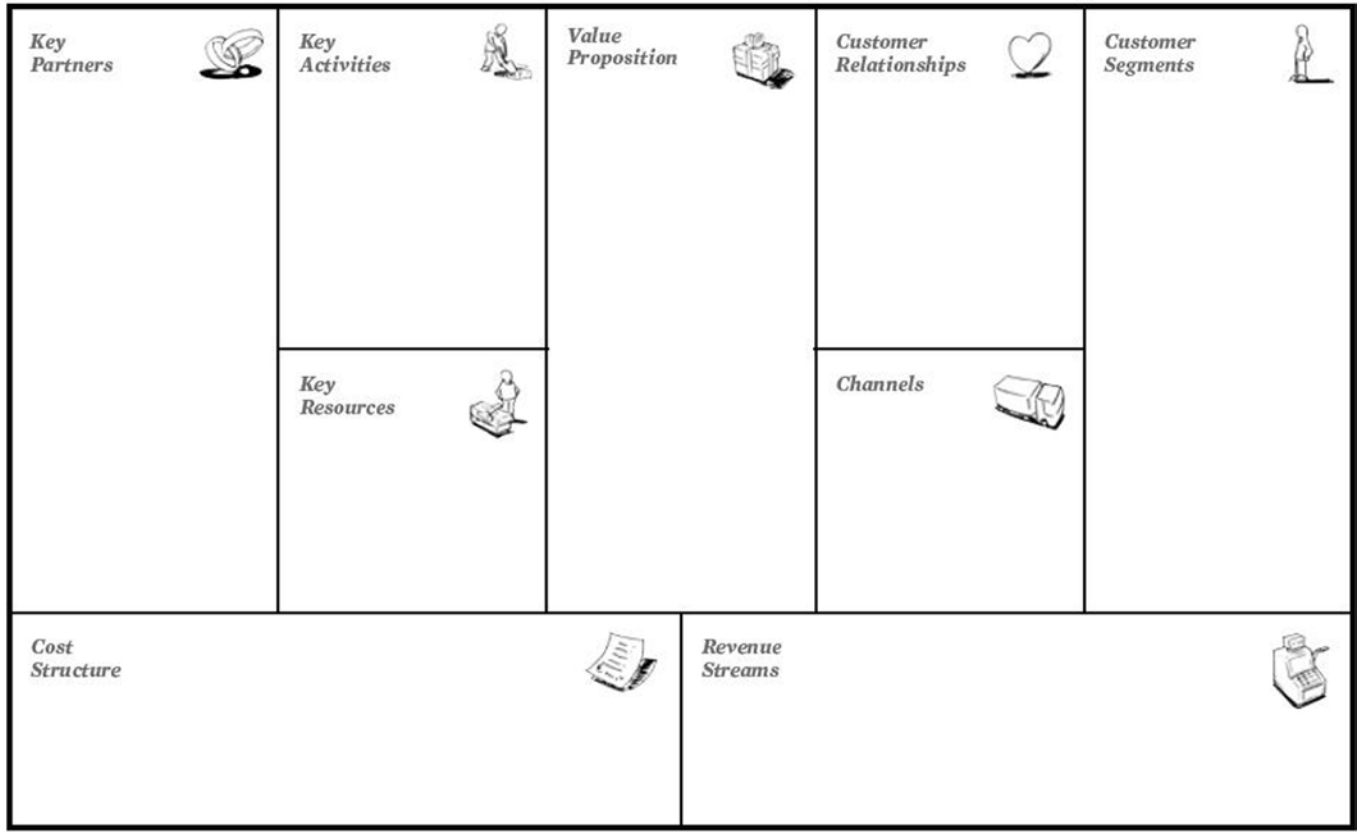
- Selection tool
- *'Focus means one thing: only do what you're good at!'* - Company 5




(Pekuri, 2015, p. 54)

# BUSINESS MODEL CANVAS

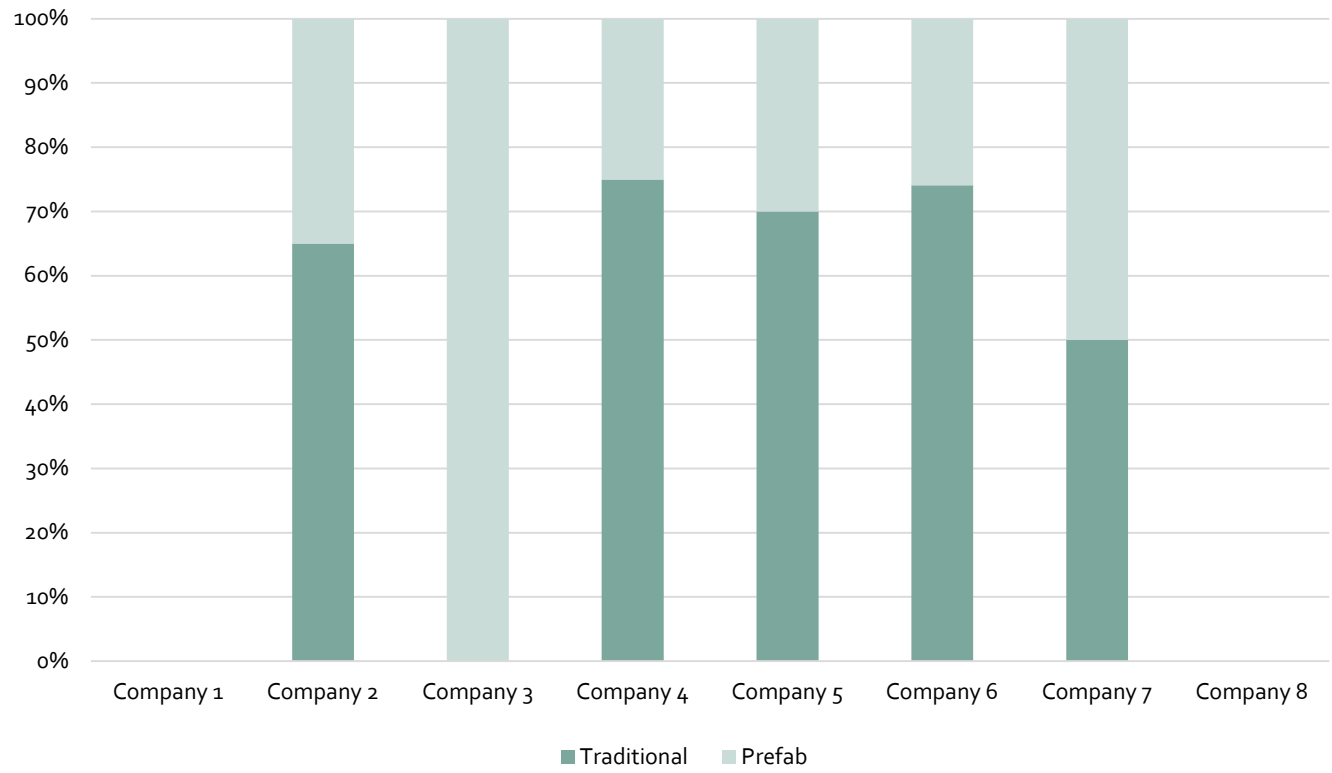
- 7 large construction companies
- 1 medium construction company
- No generic model
- No unique elements



# BUSINESS MODEL CANVAS

Value proposition

- Row-houses
- Traditional vs prefab
- Used to focus on lowest-bid
- Nowadays best-price
- Flexible/Customer made
- Sustainable



# BUSINESS MODEL CANVAS

Customer segment

- Internal client
  - Internal developer
- External client
  - External developer
  - Funds
  - Housing associations
  - Investors
  - Individuals
- User
  - Buyer
  - Tenant

# BUSINESS MODEL CANVAS

Customer relationship

- Clients
  - Long-term
  - Service department
- Users
  - Co-creation
  - Service department
- Contract
  - Design & Built
  - Design, Built & Maintain

# BUSINESS MODEL CANVAS

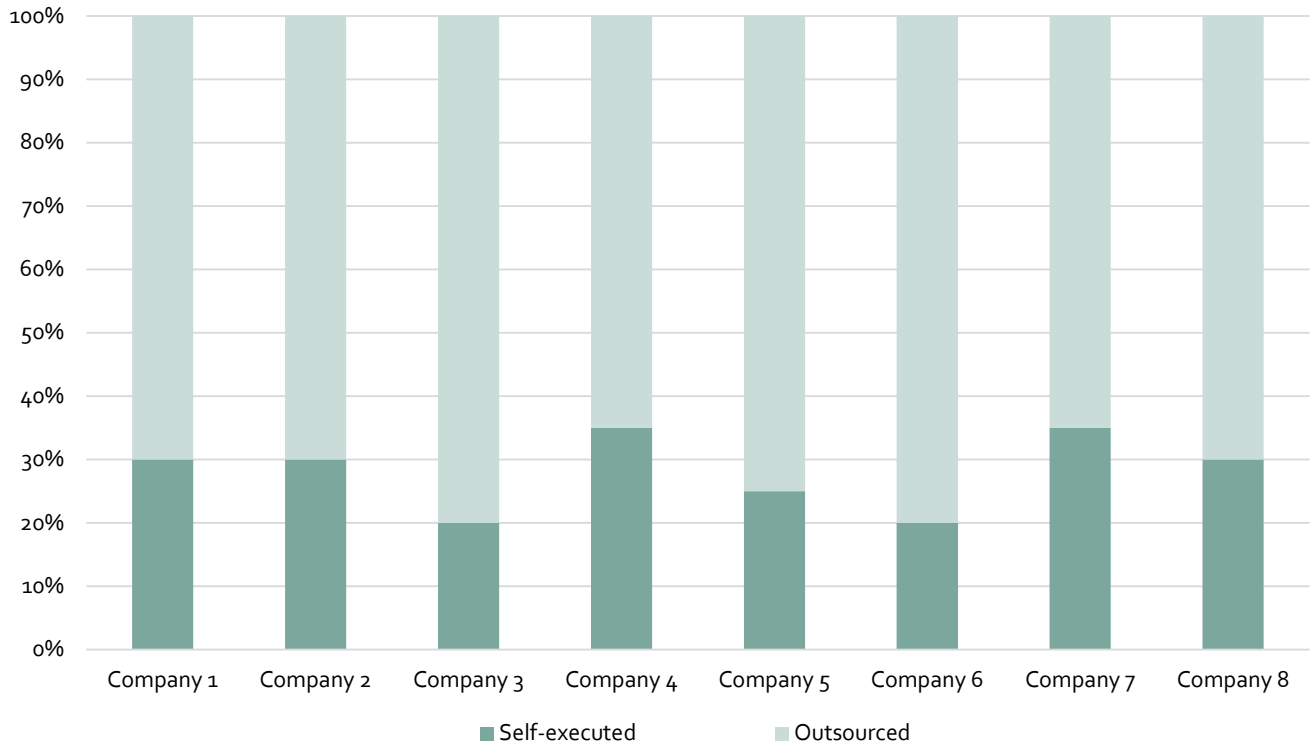
Channels

- Tenders
- Procurements
- Selection procedures
- Internal relations
- Marketing
- Showrooms

# BUSINESS MODEL CANVAS

Key Activities

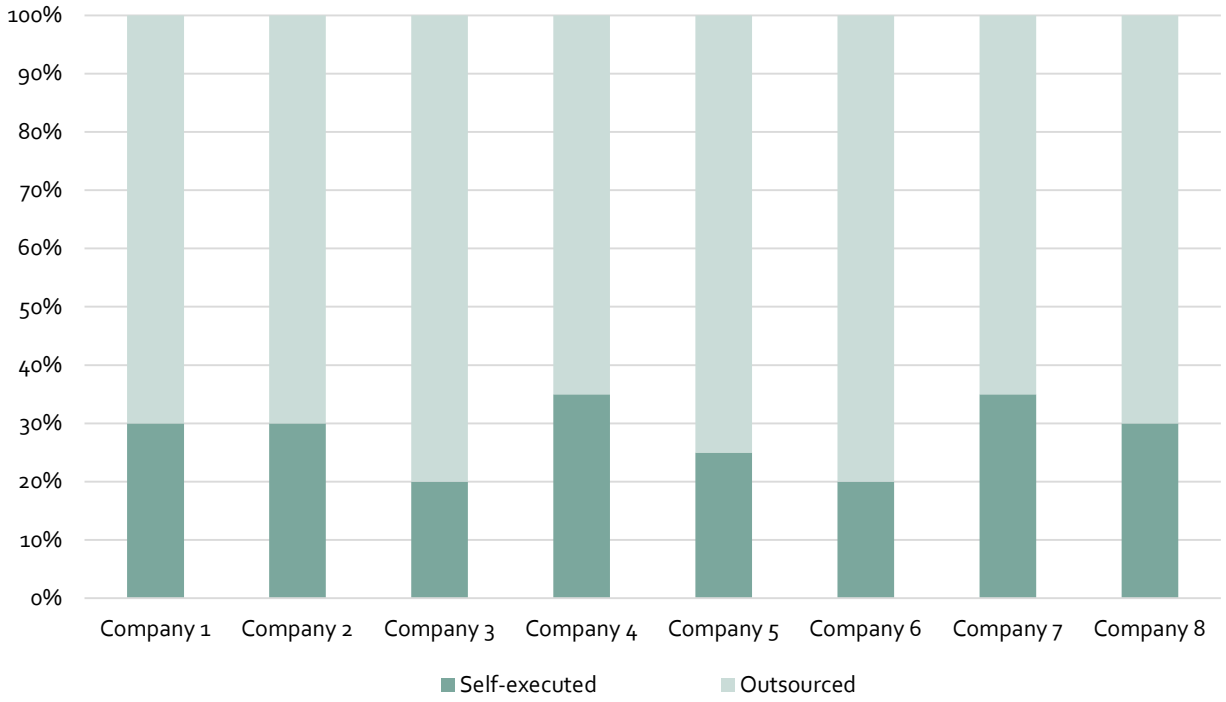
- Build
- Managing
- Maintenance
- Development
- 35 percent max. of construction tasks

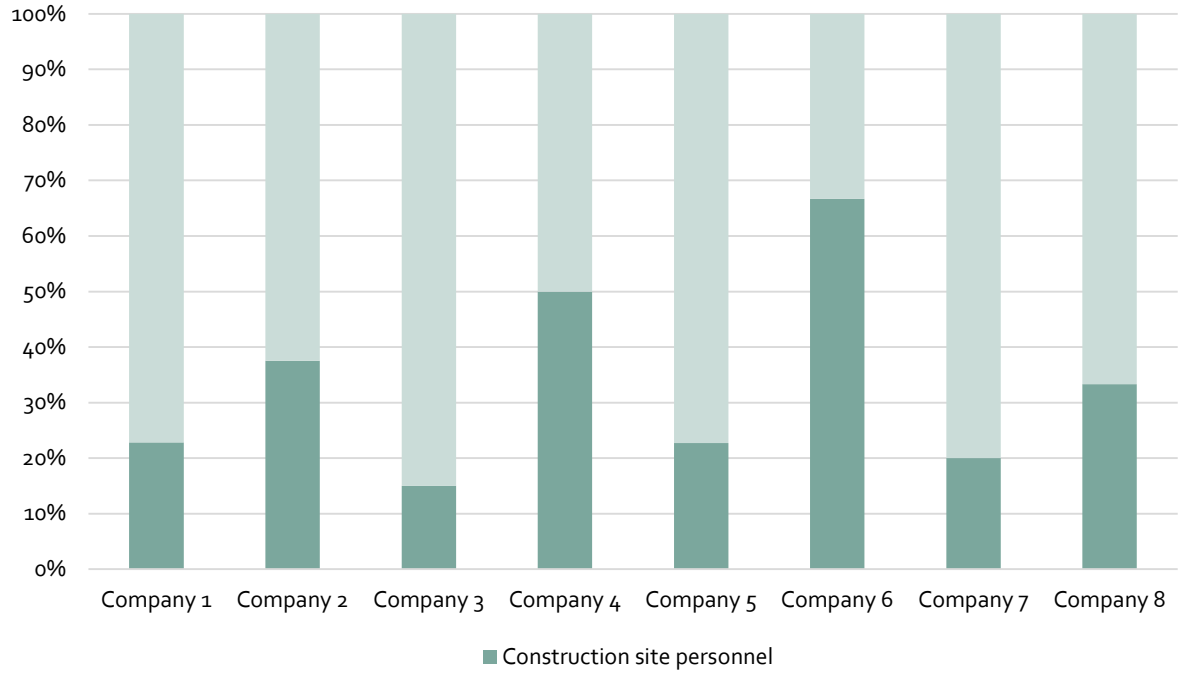


# BUSINESS MODEL CANVAS

Key Resources

- Human resources
  - Construction site personnel
  - Executive Technical Administrative personnel
- ICT
- Large construction companies:
  - Equipment service
  - Prefab factory

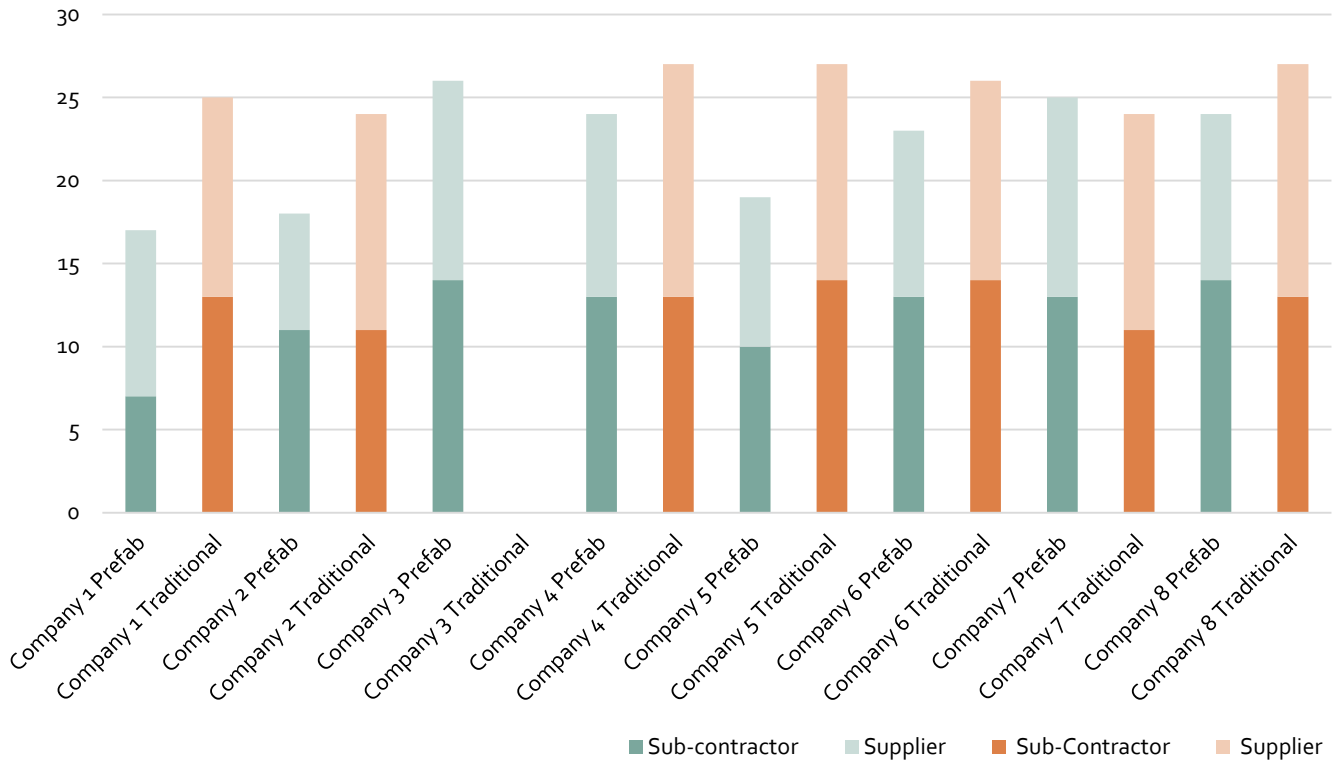


# BUSINESS MODEL CANVAS

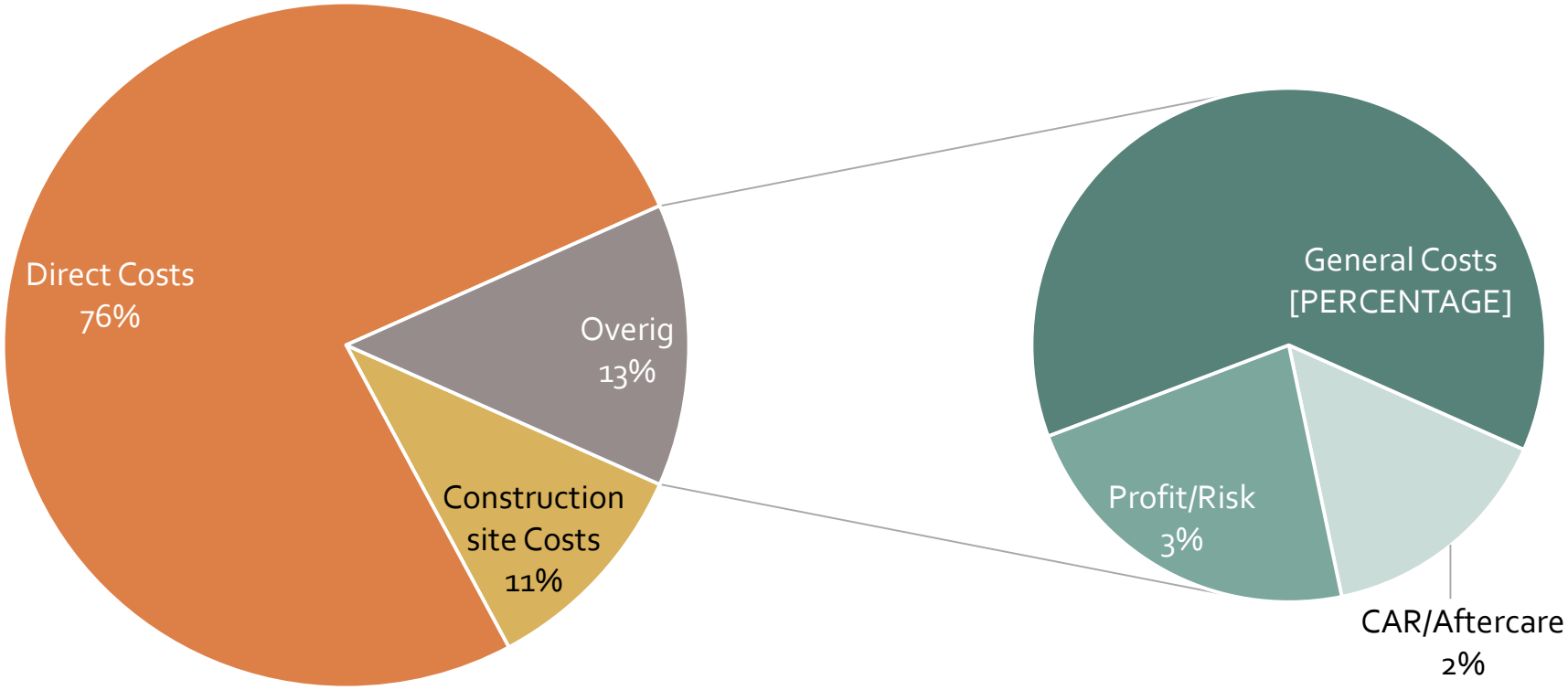
Key Partners

- Depends on construction method
- Suppliers
- Sub-contractors



# BUSINESS MODEL CANVAS

## Cost structure



# BUSINESS MODEL CANVAS

Revenue streams

- Construction
- Maintenance
- Development
- Asset sales

# DAIRY INDUSTRY

- Robots are implemented since the 90's
- Need for higher production
- Shortage of workforce
- Innovative industry
- Sector initiating both product & proces

- Due to robotization:
  - Replace humans by robot
  - Save labour costs
  - Higher efficiency
  - Fall in production costs
  - Increasing production
  - Increase animal wellfare

# EMPLOYABILITY

- Milking robot
- Feeding robot
- Calf feeding robot
- Manure robot
- Brush robot

- Application
- Neckless for the cow

| | Purchase costs |
|---|---|
| Milking robot | €190000 - €300000 |
| Feeding robot incl. 2 cars | €175000 - €275000 |
| Calf feeding robot | €10000 - €15000 |
| Manure robot | €12000 - €15000 |

# CHANGE IN BUSINESS MODEL

**Key Partners**

Additional party
Lely

**Key Activities**

Physical labour > Managing & controlling & taking action

**Key Resources**

Robots
Less workforce
or more cows

**Value Proposition**

**Customer Relationships**

**Channels**

**Customer Segments**

**Cost Structure**

Mortgage has increased
Maintenance increased.
Labour costs decreased

**Revenue Streams**

Productivity has doubles or even six-folded

ROBOTSIZATION OTHER INDUSTRIES

# ROBOT FEATURES

- 3D Concrete printing robot
  - Hardware (Automotive robot)
  - Software
  - Material: Mortar

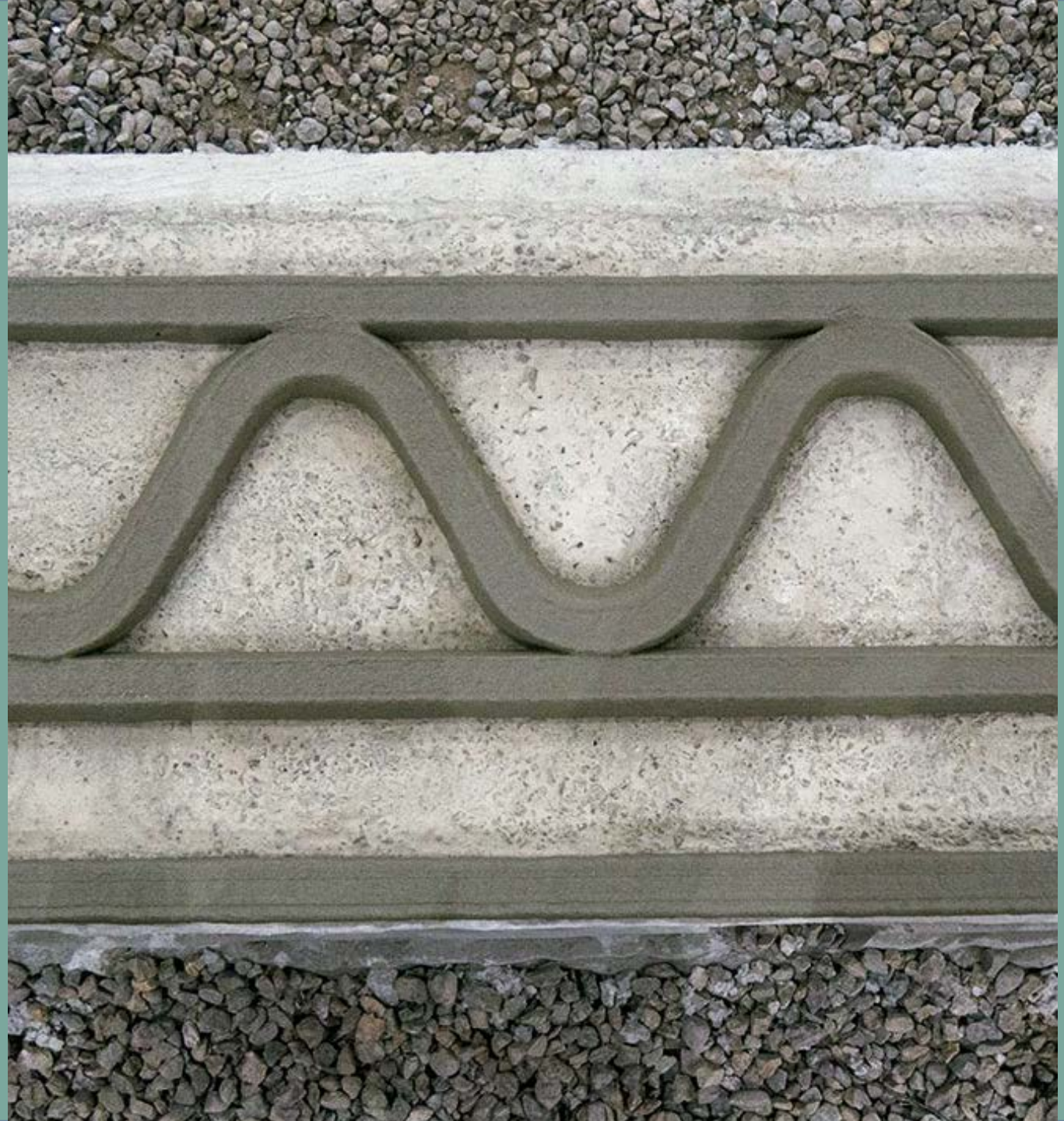
- Printing elements
- Meets the Dutch regulations

- Thinner wall packages
- Less transportation/CO2
- Cheaper than other methods
- Complex forms


| | Numbers | Unit |
|---|---|---|
| Construction time | 200 | mm/s |
| Lifespan | 10 | years |
| Maintenance/service | €35000 | year |
| Operational workforces | 2 | employees |
| Price Mortar | €21500 | dwelling |
| Robot (rent) | €800 | day |
| Robot (sale) | €350000 | robot |

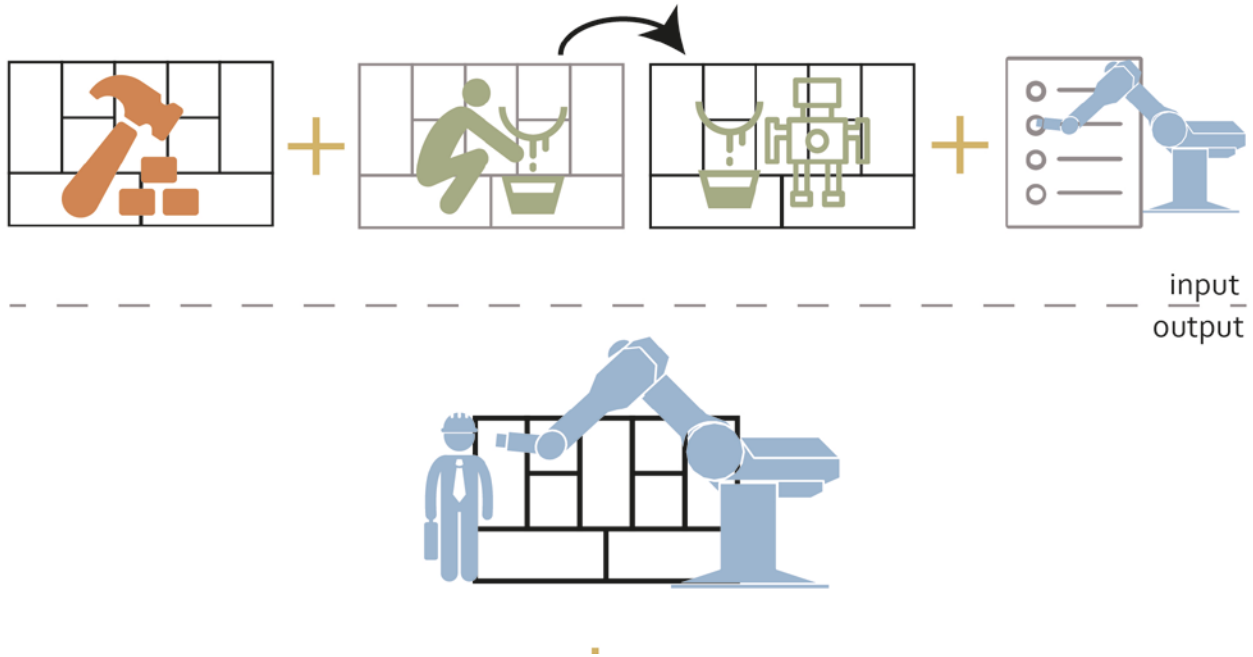
# E

# SYNTHESE & DESIGN



# SYNTHESIS

- Current business model of construction companies
- Case study of Dairy farms
- Features of the chosen robot

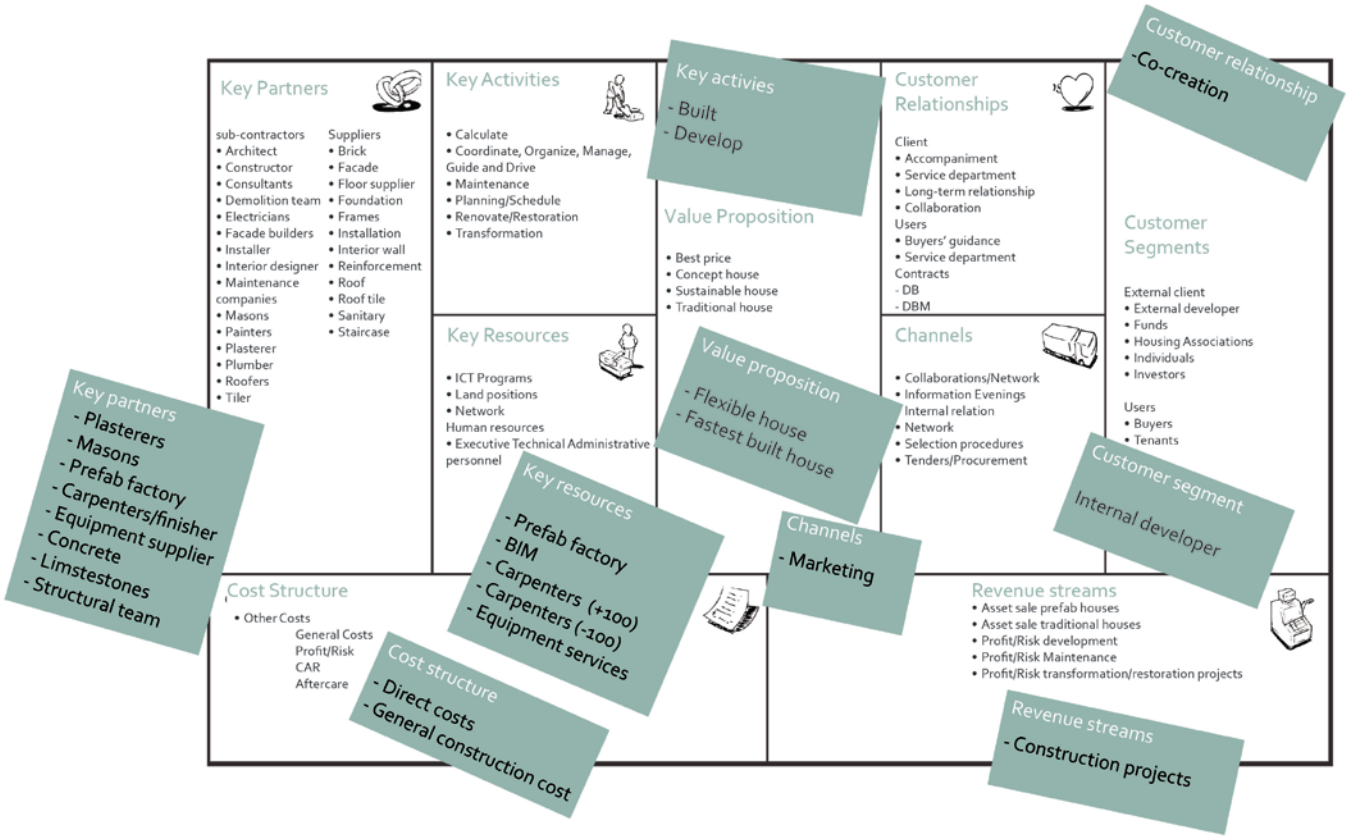


# SYNTHESIS



Current business model of construction companies

- No generic model
- All elements are merged
- Unchanged elements
- Elements that are assumed to change



# SYNTHESIS



Input of other industry

- Key resources
  - Fewer employees or higher production
  - Increasing ICT knowledge
- Key activities
  - Heavy labour intense job to a manager/controller of data
- Key partners
  - Additional partner for the service/maintenance
- Cost structure
  - Production costs haven't been reduced
  - Labour cost reduced
- Revenue streams
  - Increased due to the higher productivity

# SYNTHESIS

Input of chosen robot

- Print only walls
- Fastest construction method (75 % faster)
- Purchase of robot is €350.000
- Service costs are €35.000
- Only two workers are needed to operate
- Material is expensive but less needed
- Labour costs and material cost will reduce

## Key Partners

Sub-contractors
- Architect
- Assembly / Structural Work team
- Carpenters/ Finishers
- Constructor
- Constultants
- Demolition team
- Electricians
- Facade builders
- Installer
- Interior designer
- Maintenance companies
- Masons
- Painters
- Plumber
- Roofers
- Tiler

Suppliers
- Block/Limestn
- Brick
- Concrete
- Equipment
- Facade
- Floor
- Foundation
- Frames
- Installation
- Interior wall
- Prefab factory
- Reinforcement
- Roof
- Roof tile
- Sanitary
- Staircase

## Key Activities

- Built
- Calculate
- Coordinate, Organize, Manage, Guide and Drive
- Development
- Maintenance
- Planning/Schedule
- Renovate/Restoration
- Transformation

## Key Resources

- Equipment service
- ROBOT
- ICT Programs / BIM
- Land positions
- Network
- Prefab-concrete factory

Human resources
- Construction site personnel (-100)
- Construction site personnel (+100)
- Executive Technical Administrative personnel

## Value Proposition

- Row-house
- Freedom in form
- Marketing
- Flexible design
  Customer-oriented

## Customer Relationships

Client
- Accompaniment
- Service department
- Long-term relationship
- Collaboration

Users
- Buyers' guidance
- Co-creation
- Service department

Contracts
- Design & Built
- Design, Built & Maintain

## Channels

- Collaborations/Network
- Information Evenings
- Internal relation
- Marketing/Showroom
- Network
- Selection procedures
- Tenders/Procurement

## Customer Segments

Internal client
- In-house development department

External client
- External developer
- Funds
- Housing Associations
- Individuals
- Investors

Users
- Buyers
- Tenants

## Cost Structure

- Direct Costs
- General Construction Costs
- Other Costs
  General Costs
  Profit + Risk
  CAR
  Aftercare
- Total costs
  Compared with traditional
  Compared with prefab

## Revenue streams

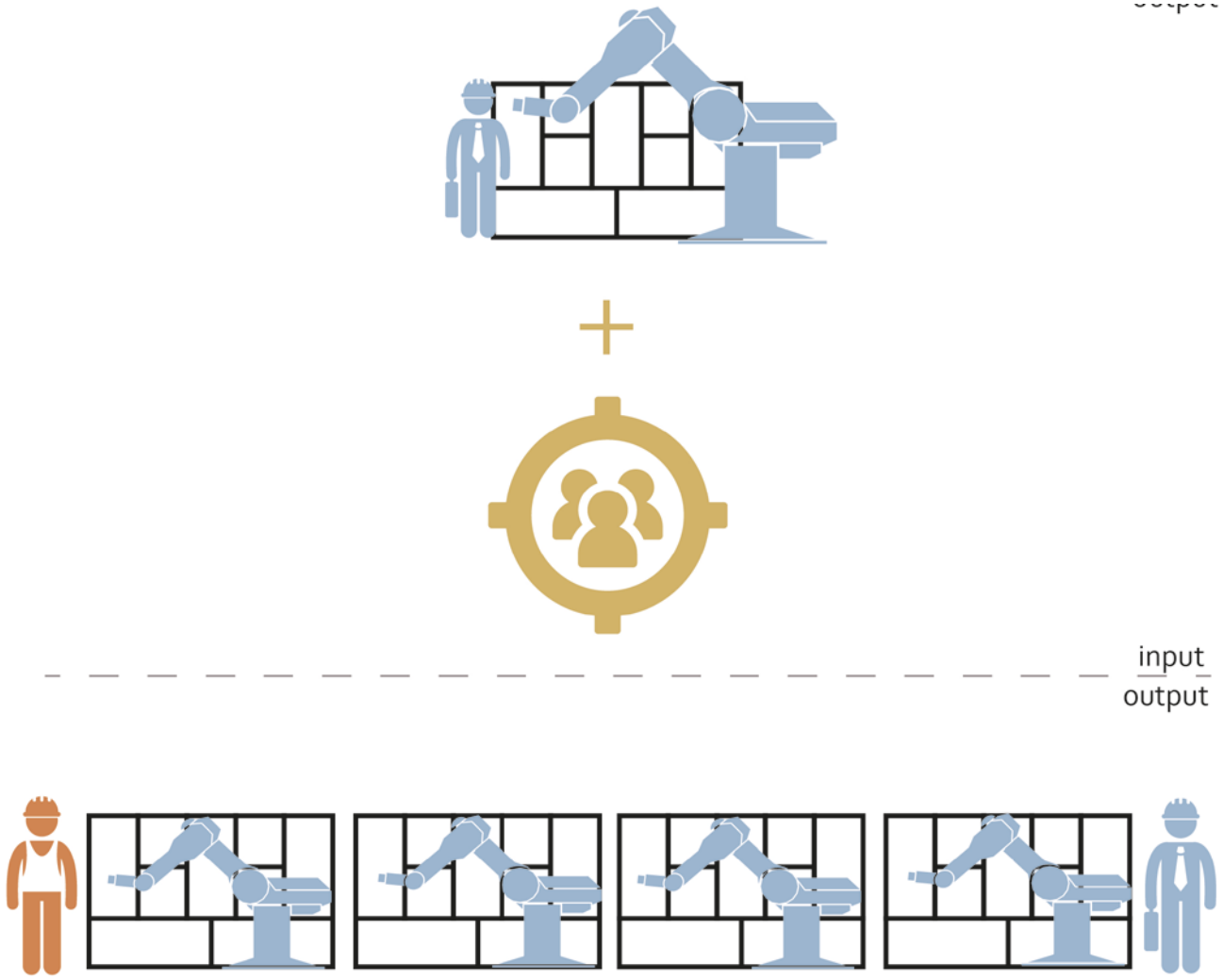
- Asset sale prefab houses
- Asset sale traditional houses
- Asset sale robotized houses
- Revenue construction
- Revenue development
- Revenue Maintenance
- Revenue transformation/restoration projects

# FOCUS GROUP

- 3 scenarios
  - Sub-contractor
  - External equipment dep.
  - Internal equipment dep.
- No influence
  - Own prefab
  - Amount of own carpenters
- Special design
- Extra ICT knowledge
- Re-educated employees
- Financial numbers are needed
- Small nuances in BM are important

# SYNTHESIS

- First draft
- Focus group



# FINAL ADJUSTED BUSINESS MODEL



- 3 Scenario's
  - Sub-contractor
  - External supplier
  - Internal equipment dep.
    - Worst case
    - Best case

# SCENARIO 1



## Key Partners

Sub-contractors
- Architect
- Assembly / Structural Work team
- Carpenters/ Finishers
- Constructor
- Constultants
- Demolition team
- Electricians
- Facade builders
- Installer
- Interior designer
- Maintenance companies
- Masons
- Painters
- Plasterer
- Plumber
- Robot company
- Roofers
- Tiler

Suppliers
- Block/Limestn
- Brick
- Concrete
- Equipment
- Facade
- Floor
- Foundation
- Frames
- Installation
- Interior wall
- Prefab factory
- Roof
- Roof tile
- Sanitary
- Staircase

## Key Activities

- Built
- Calculate
- Coordinate, Organize, Manage, Guide and Drive
- Development
- Maintenance
- Planning/Schedule
- Renovate/Restoration
- Transformation

## Key Resources

- Equipment service
- ICT Programs / BIM
- Land positions
- Network
- Prefab-concrete factory

Human resources
- Construction site personnel
- Executive Technical Administrative personnel

## Value Proposition

- Row-house
- Flexible design

Customer-oriented

## Customer Relationships

Client
- Accompaniment
- Service department
- Long-term relationship
- Collaboration

Users
- Buyers' guidance
- Co-creation
- Service department

Contracts
- Design & Built
- Design, Built & Maintain

## Channels

- Collaborations/Network
- Information Evenings
- Internal relation
- Marketing/Showroom
- Network
- Selection procedures
- Tenders/Procurement

## Customer Segments

Internal client
- In-house development department

External client
- External developer
- Funds
- Housing Associations
- Individuals
- Investors

Users
- Buyers
- Tenants

## Cost Structure

| | |
|---|---|
| Direct Costs | 77,3% |
| General Construction Costs | 13,5% |
| Other Costs | 9,2% |

General Costs (5,2%)
Profit + Risk (3%)
CAR (0,5%)
Aftercare (0,5%)

| | |
|---|---|
| Total costs | |
| Compared with traditional | +23,9 % |
| Compared with prefab | +27,3 % |

## Revenue streams

- Asset sale prefab houses
- Asset sale traditional houses
- Asset sale robotized houses
- Revenue construction
- Revenue development
- Revenue Maintenance
- Revenue transformation/restoration projects

# SCENARIO 2



## Key Partners

Sub-contractors
- Architect
- Assembly / Structural Work team
- Carpenters/ Finishers
- Constructor
- Constultants
- Demolition team
- Electricians
- Facade builders
- Installer
- Interior designer
- Maintenance companies
- Masons
- Painters
- Plasterer
- Plumber
- Roofers
- Tiler

Suppliers
- Block/Limestn
- Brick
- Concrete/cement
- Equipment: ROBOT
- Facade
- Floor
- Foundation
- Frames
- Installation
- Interior wall
- Prefab factory
- Reinforcement
- Roof
- Roof tile
- Sanitary
- Staircase



## Key Activities

- Built
- Calculate
- Coordinate, Organize, Manage, Guide and Drive
- Development
- Engineering
- Maintenance
- Planning/Schedule
- Renovate/Restoration
- Transformation

## Key Resources

- Equipment service
- ICT Programs / BIM
- Land positions
- Network
- Prefab-concrete factory

Human resources
- Construction site personnel
- Executive Technical Administrative personnel

## Value Proposition

- Row-house
- Flexible design

Customer-oriented

## Customer Relationships

Client
- Accompaniment
- Service department
- Long-term relationship
- Collaboration

Users
- Buyers' guidance
- Co-creation
- Service department

Contracts
- Design & Built
- Design, Built & Maintain

## Channels

- Collaborations/Network
- Information Evenings
- Internal relation
- Marketing/Showroom
- Network
- Selection procedures
- Tenders/Procurement

## Customer Segments

Internal client
- In-house development department

External client
- External developer
- Funds
- Housing Associations
- Individuals
- Investors

Users
- Buyers
- Tenants

## Cost Structure

- Direct Costs 76,9%
- General Construction Costs 13,9%
- Other Costs 9,2%
  - General Costs (5,2%)
  - Profit + Risk (3%)
  - CAR (0,5%)
  - Aftercare (0,5%)

- Total costs
- Compared with traditional +20,5 %
- Compared with prefab +23,7 %

## Revenue streams

- Asset sale prefab houses
- Asset sale traditional houses
- Asset sale robotized houses
- Revenue construction
- Revenue development
- Revenue Maintenance
- Revenue transformation/restoration projects

# SCENARIO 3 – Worst case



## Key Partners

Sub-contractors
- Architect
- Assembly / Structural Work team
- Carpenters/ Finishers
- Constructor
- Constultants
- Demolition team
- Electricians
- Facade builders
- Installer
- Interior designer
- Maintenance companies
- Maintenance service robot
- Masons
- Painters
- Plasterer
- Plumber
- Roofers
- Tiler

Suppliers
- Block/Limestn
- Brick
- Concrete/cement
- Equipment
- Facade
- Floor
- Foundation
- Frames
- Installation
- Interior wall
- Prefab factory
- Reinforcement
- Roof
- Roof tile
- Sanitary
- Staircase

## Key Activities

- Built
- Calculate
- Coordinate, Organize, Manage, Guide and Drive
- Development
- Engineering
- Maintenance
- Planning/Schedule
- Renovate/Restoration
- Transformation

## Key Resources

- Equipment service
- ROBOT
- ICT Programs / BIM
- Land positions
- Network
- Prefab-concrete factory

Human resources
- Construction site personnel
- Executive Technical Administrative personnel

## Value Proposition

- Row-house
- Flexible design

Customer-oriented

## Customer Relationships

Client
- Accompaniment
- Service department
- Long-term relationship
- Collaboration

Users
- Buyers' guidance
- Co-creation
- Service department

Contracts
- Design & Built
- Design, Built & Maintain

## Channels

- Collaborations/Network
- Information Evenings
- Internal relation
- Marketing/Showroom
- Network
- Selection procedures
- Tenders/Procurement

## Customer Segments

Internal client
- In-house development department

External client
- External developer
- Funds
- Housing Associations
- Individuals
- Investors

Users
- Buyers
- Tenants

## Cost Structure

| | |
|---|---|
| Direct Costs | 76,5% |
| General Construction Costs | 14,3% |
| Other Costs | 9,2% |
| General Costs (5,2%) | |
| Profit + Risk (3%) | |
| CAR (0,5%) | |
| Aftercare (0,5%) | |

| | |
|---|---|
| Total costs | |
| Compared with traditional | +25,11 % |
| Compared with prefab | +28,5 % |

## Revenue streams

- Asset sale prefab houses
- Asset sale traditional houses
- Asset sale robotized houses
- Revenue construction
- Revenue development
- Revenue Maintenance
- Revenue transformation/restoration projects

# SCENARIO 3 – Best case



## Key Partners

Sub-contractors
- Architect
- Assembly / Structural Work team
- Carpenters/ Finishers
- Constructor
- Constultants
- Demolition team
- Electricians
- Facade builders
- Installer
- Interior designer
- Maintenance companies
- Maintenance service robot
- Masons
- Painters
- Plumber
- Roofers
- Tiler

Suppliers
- Block/Limestn
- Brick
- Concrete
- Equipment
- Facade
- Floor
- Foundation
- Frames
- Installation
- Interior wall
- Prefab factory
- Reinforcement
- Roof
- Roof tile
- Sanitary
- Staircase

## Key Activities

- Built
- Calculate
- Coordinate, Organize, Manage, Guide and Drive
- Development
- Engineering
- Maintenance
- Planning/Schedule
- Renovate/Restoration
- Transformation

## Key Resources

- Equipment service
- ROBOT
- ICT Programs / BIM
- Land positions
- Network
- Prefab-concrete factory

Human resources
- Construction site personnel
- Executive Technical Administrative personnel

## Value Proposition

- Row-house
- Flexible design

Customer-oriented

## Customer Relationships

Client
- Accompaniment
- Service department
- Long-term relationship
- Collaboration

Users
- Buyers' guidance
- Co-creation
- Service department

Contracts
- Design & Built
- Design, Built & Maintain

## Channels

- Collaborations/Network
- Information Evenings
- Internal relation
- Marketing/Showroom
- Network
- Selection procedures
- Tenders/Procurement

## Customer Segments

Internal client
- In-house development department

External client
- External developer
- Funds
- Housing Associations
- Individuals
- Investors

Users
- Buyers
- Tenants

## Cost Structure

| | |
|---|---|
| Direct Costs | 74,7% |
| General Construction Costs | 16,1% |
| Other Costs | 9,2% |

General Costs (5,2%)
Profit + Risk (3%)
CAR (0,5%)
Aftercare (0,5%)

| | |
|---|---|
| Total costs | |
| Compared with traditional | +3,7 % |
| Compared with prefab | +6,6 % |

## Revenue streams

- Asset sale prefab houses
- Asset sale traditional houses
- Asset sale robotized houses
- Revenue construction
- Revenue development
- Revenue Maintenance
- Revenue transformation/restoration projects

# F CONCLUSIONS

# CONCLUSIONS



- It is not possible to design an generic business model for all the large companies
- 3 different  scenarios
  - First is most promessing for practice
  - Third best case is financially most feasibile
- Robot will not competitive to traditional or prefab method
- Great urgency is needed

# DISCUSSION



- Literature is not the similar to practice
- Definition of robot had to be adjusted (AI)
- Practice would rather invest and research masonry robots or finsihing robot, since they have a bigger (financial) share in the construction process.
- 3D Robot is best used in case of standardized row-houses
  - Optimized in prefabricated factories
- Research questions were defined with expactations of one general business model
- Case study is a complete different industry
  - Only a process innovation > project and process innovation
- First design optimistic
  - Only based on the features of the robot developer
- Higher urgency needed (before implementation)
  - Increase shortage of crafstmen
  - Prefab factories run out of capacity

# DISCUSSION



- Higher production costs
  - Matching the expactations of dairy farms
  - Still financial feasible
- Robot developer as sub-contractor
  - Increase the competition
- Construction industry is conservative
  - Expect the sub-contractor to innovate

# RECOMMENDATIONS



- Practice

  Construction companies
  - More attention should be given to business models
  - Innovation is only introduced by sub-contractors
    - Increase competition
  - In order to remain at the same market possition construction companies have to innovate
  - 3D concrete printing robot is not satisfying enough, small share in the process

  3D concrete printing robot company
  - Rethink business strategy
  - 3D printing can be much cheaper compared to competitors
  - Decrease price of mortar
  - Service costs are too high

# RECOMMENDATIONS



- Research
  - Other robots can be researched: Masonry and finishing robot
  - Case studies in other sectors can be conducted
  - Legislation of robots can be researched
  - Construction time can be researched
  - Difference between large en small companies can be researched