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
The construction industry:

- One of the oldest professions
- Largest economic sector
  - 9.6 – 11.4 % GDP
    (Deloitte, 2016)
- Conservative and traditional
  - Methods have hardly changed

INTRODUCTION

(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 standardisation
  - Medium level of prefabrication
  - Numerous 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
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)
INTRODUCTION

PROBLEM STATEMENT

CURRENT SITUATION

BUSINESS MODEL

POSSIBLE SITUATION
How can Dutch construction companies adjust their business model in order to make robots at the construction site possible?
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: Manipulation

- 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)
On-site robots

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

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

(Bock, 2006; Bulusu, 2015; Elattar, 2008; Abderrahim & Balaguer, 2008)
ROBOTS: STATE OF THE ART

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 occurring 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**

<table>
<thead>
<tr>
<th>Companies</th>
<th>Revenue 2016 X 1,000,000</th>
<th>Operating field</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAM</td>
<td>7423</td>
<td>Infra, RE, Residential</td>
</tr>
<tr>
<td>Volker Wessels</td>
<td>4906</td>
<td>Infra, RE, Residential, Installations</td>
</tr>
<tr>
<td>Boskalis</td>
<td>3240</td>
<td>Infra, Civil, Offshore, Maritime</td>
</tr>
<tr>
<td>Van Oord</td>
<td>2579</td>
<td>Civil, Offshore</td>
</tr>
<tr>
<td>Heijmans</td>
<td>1979</td>
<td>Infra, Civil, RE, Residential, Utility</td>
</tr>
<tr>
<td>Strukton</td>
<td>1907</td>
<td>Infra, Civil, RE, Installations</td>
</tr>
<tr>
<td>TBI</td>
<td>1557</td>
<td>Infra, Residential, Utility, Technique</td>
</tr>
<tr>
<td>Dura Vermeer</td>
<td>1052</td>
<td>Infra, RE, Residential, Utility</td>
</tr>
<tr>
<td>Ballast Nedam</td>
<td>850</td>
<td>Infra, RE, Residential, Utility</td>
</tr>
<tr>
<td>Van Wijnen</td>
<td>693</td>
<td>RE, Residential, Utility</td>
</tr>
</tbody>
</table>

(Cobouw, 2016)
CHANGING ROLE

- Traditionally active in execution phase
  - Construction tasks

- Shifted to construction management companies
  - Outsourcing activities

- More ground in the construction process
  - Also developers
  - Integration of design and construction
  - To preserve own construction capacity
## CONSTRUCTION METHODS

<table>
<thead>
<tr>
<th></th>
<th>Casting</th>
<th>Masonry</th>
<th>Wooden skeleton</th>
<th>Prefab elements</th>
<th>Prefab units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preparation time</strong></td>
<td>Medium</td>
<td>Short</td>
<td>Long</td>
<td>Long</td>
<td>Long</td>
</tr>
<tr>
<td><strong>Construction site</strong></td>
<td>Big</td>
<td>Medium</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Construction time</strong></td>
<td>Medium</td>
<td>Long</td>
<td>Short</td>
<td>Super Short</td>
<td>Super short</td>
</tr>
<tr>
<td><strong>Consumer-oriented</strong></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Equipment cost</strong></td>
<td>Super high</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Finishing</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Super high</td>
</tr>
<tr>
<td><strong>Labour intensity</strong></td>
<td>Low</td>
<td>Super high</td>
<td>Medium</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Scale of the project</strong></td>
<td>Big</td>
<td>Small, variation</td>
<td>Small</td>
<td>Big</td>
<td>Big</td>
</tr>
<tr>
<td><strong>Weather dependency</strong></td>
<td>Super high</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
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 consensus 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
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
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 MODELS IN PRACTICE

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

Key Partners
- Depends on construction method
- Suppliers
- Sub-contractors
BUSINESS MODEL CANVAS

Cost structure

- Direct Costs: 76%
- Construction site Costs: 11%
- Overig: 13%
- CAR/Aftercare: 2%
- General Costs: [PERCENTAGE]
- Profit/Risk: 3%
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 & process

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

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

- Application
- Neckless for the cow

<table>
<thead>
<tr>
<th>Robot Type</th>
<th>Purchase costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milking robot</td>
<td>€190000 - €300000</td>
</tr>
<tr>
<td>Feeding robot incl. 2 cars</td>
<td>€175000 - €275000</td>
</tr>
<tr>
<td>Calf feeding robot</td>
<td>€10000 - €15000</td>
</tr>
<tr>
<td>Manure robot</td>
<td>€12000 - €15000</td>
</tr>
</tbody>
</table>
## Change in Business Model

<table>
<thead>
<tr>
<th>Key Partners</th>
<th>Key Activities</th>
<th>Value Proposition</th>
<th>Customer Relationships</th>
<th>Customer Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional party</td>
<td>Physical labour &gt; Managing &amp; controlling &amp; taking action</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lely</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Resources</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Robots</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less workforce or more cows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost Structure</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortgage has increased</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance increased.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour costs decreased</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revenue Streams</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity has doubles or even six-folded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th>Numbers</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction time</td>
<td>200</td>
<td>mm/s</td>
</tr>
<tr>
<td>Lifespan</td>
<td>10</td>
<td>years</td>
</tr>
<tr>
<td>Maintenance/service</td>
<td>€35000</td>
<td>year</td>
</tr>
<tr>
<td>Operational workforces</td>
<td>2</td>
<td>employees</td>
</tr>
<tr>
<td>Price Mortar</td>
<td>€21500</td>
<td>dwelling</td>
</tr>
<tr>
<td>Robot (rent)</td>
<td>€800</td>
<td>day</td>
</tr>
<tr>
<td>Robot (sale)</td>
<td>€350000</td>
<td>robot</td>
</tr>
</tbody>
</table>
SYNTHESIS

- Current business model of construction companies
- Case study of Dairy farms
- Features of the chosen robot
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
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
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
  - Consultants
  - Demolition team
  - Electricians
  - Facade builders
  - Installer
  - Interior designer
  - Maintenance companies
  - Masons
  - Painters
  - Plasterer
  - Plumber
  - Roofing company
  - Roofers
  - Tiler

**Key Activities**
- **Built**
  - Calculate
  - Coordinate, Organize, Manage, Guide and Drive
  - Development
  - Maintenance
  - Planning/Schedule
  - Renovate/Restoration
  - Transformation
- **Row-house**
- **Flexible design**
- **Customer-oriented**

**Value Proposition**

**Customer Relationships**
- Client
  - Accompaniment
  - Service department
  - Long-term relationship
  - Collaboration
  - Users
  - Buyers' guidance
  - **Co-creation**
  - Service department
  - Contracts
  - Design & Built
  - Design, Built & Maintain

**Customer Segments**
- Internal client
  - In-house development department
- External client
  - External developer
  - Funds
  - Housing Associations
  - Individuals
  - Investors

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

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

**Human resources**
- Construction site personnel
- Executive Technical Administrative personnel

**Cost Structure**
- **Direct Costs**
- **General Construction Costs**
- **Other Costs**
  - General Costs (5.7%)
  - Profit + Risk (3%)
  - CAR (0.5%)
  - Aftercare (0.5%)
  - Total costs
    - Compared with traditional: 77.3% +23.9% +27.3%
    - Compared with prefab: 13.5% 9.7% 3.5%

**Revenue streams**
- Asset sale prefab houses
- Asset sale traditional houses
- Asset sale roboticized houses
- Revenue construction
- Revenue development
- Revenue Maintenance
- Revenue transformation/restoration projects
### SCENARIO 2

#### Key Partners
- Sub-contractors:
  - Architect
  - Assembler/Structural/Work team
  - Carpenters/Finishers
  - Constructor
  - Consultants
  - Demolition team
  - Electricians
  - Facade builders
  - Installer

- Suppliers:
  - Reinforcement
  - Roof
  - Roof tile
  - Sanitary
  - Staircase
  - Block/Limestone
  - Brick

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

#### Key Resources
- **Reinforcement**
- **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
  - Service department
  - Contracts
  - Design & Built
  - Design, Built & Maintain

- **External client**
  - **In-house development department**
  - **External developer**
  - **Funds**
  - **Housing Associations**
  - **Individuals**
  - **Investors**

- **Users**
  - **Buyers**
  - **Tenants**

#### Customer Segments
- **Channels**
  - Collaborations/Network
  - Information Evenings
  - Internal relation
  - Marketing/Showroom
  - Network
  - Selection procedures
  - Tenders/Procurement

#### Cost Structure
- **Direct Costs**: 76.9%
- **General Construction Costs**: 13.3%
- **Profit + Risk**: 9.2%
- **CAR**: 0.5%
- **Aftercare**: 0.5%

- **Other Costs**
  - **General Costs (5.2%)**

- **Total costs** Compared with traditional prefab: +120.5%
- 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
  - Consultant
  - Demolition team
  - Electricians
  - Facade builders
  - Installer
- **Suppliers**
  - Block/Limestone
  - Brick
  - Concrete/Aggregate
  - Equipment
  - Facade
  - Floor
  - Foundation
  - Frames
  - Installation
  - Interior wall
  - Prefab factory

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

#### Value Proposition
- **Row-house**
- **Flexible design**
- **Customer-oriented**

#### Key Resources
- **Equipment service**
- **ROBOT**
- **ICT Programs / BIM**
- **Land positions**
- **Network**
- **Prefabrication factory**
- **Construction site personnel**
- **Executive Technical Administrative personnel**

#### Customer Relationships
- **Client**
  - Accompaniment
  - Service department
  - Long-term relationship
  - Collaboration
  - Users
  - Buyers’ guidance
  - Co-creation
  - Service department contracts
  - Design & Built
  - Design, Built & Maintain

#### Customer Segments
- **Internal client**
  - In-house development department
- **External client**
  - External developer
  - Funds
  - Housing Associations
  - Individuals
  - Investors

#### Channels
- **Collaborations/Network**
- **Information Evenings**
- **Internal Relations**
  - **Marketing/Showroom**
  - **Network**
  - Selection procedures
  - Tenders/Procurement

#### Revenue Streams
- **Asset sale prefab houses**
- **Asset sale traditional houses**
- **Asset sale roboticized houses**
- **Revenue construction**
- **Revenue development**
- **Revenue Maintenance**
- **Revenue transformation/restoration projects**

#### Cost Structure
- **Direct Costs**
  - 76.5%
- **General Construction Costs**
  - 14.3%
- **Other Costs**
  - 9.2%
  - **General Costs (9,2%**
  - **Profit + Risk (3%)**
  - **CAR (0,5%)**
  - **Aftercare (0,5%)**

- **Total costs**
  - Compared with traditional
  - Compared with prefab
  - **+35.11 %
  - +26.5 %**
SCENARIO 3 – Best case

**Key Partners**
- Sub-contractors: Architect, Assembly / Structural Work team, Carpenters/Finishers, Constructor, Consultants, Demolition team, Electricians, Facade builders, Installer
- Key Resources: Reinforcement, Roof, Roof tile, Sanitary, Staircase, ROBOT, Land positions, Network, Prefab-concrete factory
- Human resources: Construction site personnel, Executive Technical Administrative personnel
- Cost Structure: Direct Costs 74.7%, General Construction Costs 16.1%, Other Costs 9.2%

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

**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

**Customer Segments**
- Internal client
  - In-house development department
- External client
  - External developer
  - Funds
  - Housing Associations
  - Individuals
  - Investors
- Users
  - Buyers
  - Tenants

**Channels**
- Collaborations/Network
- Information Evenings
- Internal relation
- Network
- Selection procedures
- Tenders/Procurement

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

- It is not possible to design an generic business model for all the large companies

- 3 different scenarios
  - First is most promising for practice
  - Third best case is financially most feasible

- 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 finishing 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 expectations 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 craftsmen
  - Prefab factories run out of capacity
DISCUSSION

- Higher production costs
  - Matching the expectations of dairy farms
  - Still financially 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 position 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 and small companies can be researched