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Research Design

Appendix A *Exploratory Interview Design*
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(Picture Royal HaskoningDHV, case study project 1A in Ethiopia)

A

Exploratory Interview Design

Exploratory interviewees				
Perspective	Company	Function	Experience	Reference interview (I)
Service supplier	RHDHV	Director Business Development	+/- 40 years	I-1 (Exploratory interview, 2nd of May 2018 - 1)
Service supplier	RHDHV	Senior Project Manager / Contract Manager	+/- 40 years	I-2 (Exploratory interview, 14th of May 2018)
Service supplier	RHDHV	Project Manager and Domain Expert Chains & Logistics	+/- 35 years	I-3 (Exploratory interview, 2nd of May 2018 - 2)
Service supplier	RHDHV	Consultant FMCG	+/- 35 years	I-4 (Exploratory interview, 27th of March 2018)
Service supplier	RHDHV	Project Manager FMCG	+/- 15 years	I-5 (Exploratory interview, 8th of May 2018 - 1)
Service supplier	RHDHV	Project Manager FMCG	+/- 15 years	I-6 (Exploratory interview, 23rd of March 2018)
Service supplier	RHDHV	Project Manager	+/- 10 years	I-7 (Exploratory interview, 7th of May 2018)
Service supplier	RHDHV	Business Case Consultant	+/- 5 years	I-8 (Exploratory interview, 8th of May 2018 - 2)

Table A-1 - Exploratory interviewees

Exploratory interview framework				
	Initiation phase	Design phase	Construction phase	Exploitation phase
Construction projects	I-4 & I-8	I-1, I-2, I-5, I-6 & I-7	I-2	I-4
Construction projects in FMCG manufacturing industry				

Table A-2 - Exploratory interview framework

B

Case Study Design

B.1. Case Study Projects

Case study projects					
FMCG manufacturers	1		2		3
Case study projects	1A	1B	2A	2B	3
Countries projects	Ethiopia	Vietnam	Russia	Pakistan	Nigeria

Table B-1 - Case study projects

B.2. Case Study Interviews

Interviewees FMCG manufacturer perspective			
Perspective	Company	Function	Reference interview (I)
FMCG manufacturer	1	Portfolio Manager Innovation & Investments	I-1 (Case study interview, 7th of June 2018)
FMCG manufacturer	1	Project Manager	I-2 (Case study interview, 27th of June 2018)
FMCG manufacturer	1	Project Manager	I-3 (Case study interview, 18th of June)
FMCG manufacturer	2	Senior Project Manager	I-4 (Case study interview, 12th of June 2018)
FMCG manufacturer	3	Senior Project Manager	I-5 (Case study interview, 19th of July 2018)

Table B-2 - Case study interviews - Interviewees FMCG manufacturer perspective

Interview framework FMCG manufacturer perspective			
	FMCG manufacturer 1	FMCG manufacturer 2	FMCG manufacturer 3
Construction projects	I-1	I-4	I-5
Construction projects in FMCG manufacturing industry			
Construction projects of specific FMCG manufacturer	I-2 & I-3		

Table B-3 - Case study interviews - Interview framework FMCG manufacture perspective

Interviewees service supplier perspective (i.e. RHDHV)			
Perspective	Company	Function	Reference interview (I)
Service supplier	RHDHV	Senior Project Manager	I-1 (Case study interview, 14th of June 2018)
Service supplier	RHDHV	Senior Project Manager	I-2 (Case study interview, 13th of June 2018)
Service supplier	RHDHV	Engineering Director	I-3 (Case study interview, 19th of June 2018)
Service supplier	RHDHV	Global Business Developer	I-4 (Case study interview, 4th of June 2018)
Service supplier	RHDHV	Project Manager / Architect	I-5 (Case study interview, 15th of June 2018 - 1)
Service supplier	RHDHV	Project Manager	I-6 (Case study interview, 15th of June 2018 - 2)
Service supplier	RHDHV	Junior Project Manager	I-7 (Case study interview, 6th of June 2018)
Service supplier	RHDHV	Global Engineering and Technology Leader	I-8 (Case study interview, 27th of June 2018)

Table B-4 - Case study interviews - Interviewees service supplier perspective

Interview framework service supplier perspective (i.e. RHDHV)			
Construction projects in FMCG manufacturing industry	I-1, I-2, I-3, I-4 & I-6		
	RDHVH with FMCG manufacturer 1	RDHVH with FMCG manufacturer 2	RDHVH with FMCG manufacturer 3
Construction projects of specific FMCG manufacturer	I-1, I- 2, I-3 & I-4	I-6	I-3 & I-4

Table B-5 - Case study interviews - Interview framework service supplier perspective

Interviewees process product supplier perspective (i.e. original equipment manufacturer (OEM))			
Perspective	Company	Function	Reference interview (I)
Process product supplier	OEM	Head of Plant Engineering and Consulting	I-1 (Case study interview, 4th of July 2018)
Process product supplier	OEM	Key Account Director FMCG manufacturer 1	

Table B-6 - Case study interviews - Interviewees process product supplier perspective

Interview framework process product supplier perspective (i.e. original equipment manufacturer (OEM))			
Construction projects	I-1		
Construction projects in FMCG manufacturing industry			
	OEM with FMCG manufacturer 1		OEM with FMCG manufacturer 3
Construction projects of specific FMCG manufacturer	I-1		I-1

Table B-7 - Case study interviews - Interview framework process product supplier perspective

Interview framework case study projects				
Case study project	Interview FMCG manufacturer perspective (Table B-2)		Interview service supplier perspective (Table B-4)	
1A	I-2	*Project Manager*	I-1	*Sr. Project Manager*
			I-5	*Jr. Project Manager*
1B	I-3	*Project Manager*	I-2	*Sr. Project Manager*
2A	I-4	*Global Project Manager*	I-6	*Project Director*
2B			I-6	*Project Director*
			I-7	*Project Manager*
3	I-5	*Project Director*	I-4	*Project Director*
			I-3	*Project Manager*
			I-8	*Integration Manager*

Table B-8 - Case study interviews - Interview framework case study projects

Interview guide FMCG manufacturer

General questions

Corporate structure

- What aspects of the **corporate structure** of FMCG manufacturer influence brown-/greenfield projects?
- How is FMCG manufacturer's **corporate structure** divided into **global** and **local** organisations?
- What are FMCG manufacturer's **decision-making** steps related to **Capex** [1] **investments**?
- What are FMCG manufacturer's **decision-making** steps related to **Opex** [2] **investments**?

Standardized

- To which extent are FMCG manufacturer's **breweries standardized**?
- To which extent are FMCG manufacturer's **brown/-greenfield projects standardized**? (standardized requirements, standardized project organisation, etc.)

Industry 4.0

- Does FMCG manufacturer notice a shift in client demands in the trend of **Industry 4.0**? (individualized products, time-to-market, from push to pull, etc.)
- What does FMCG manufacturer do itself within this trend? (research, development, innovation)
- What does FMCG manufacturer see as **challenges** within this trend?
- What does FMCG manufacturer see as **opportunities** within this trend?
- What are the most important aspects/themes/etc. the coming **15 years** that FMCG manufacturer takes into account defining its **strategy**?

Construction projects of specific FMCG manufacturer

Project drivers

- What are the common **project drivers** of FMCG manufacturer's brown-/green field projects?
- What are the **reasons** for these **project drivers**?
- How are these **project drivers** communicated to the stakeholders of the projects?

Phasing and timeline

- What are the common **phases/steps** of FMCG manufacturer's brown-/greenfield projects?
- What is the common **duration** of these phases/steps?
- What is the rule of thumb for the **timeline** (+ durations) towards the first brew?
- What are the common **reasons** for **time overruns**? And what are the **consequences**?
- What are the common **reasons** for **budget overruns**? And what are the **consequences**?

Problems, challenges and opportunities

- What **problems/challenges** does FMCG manufacturer often face during its brown-/greenfield projects?
- What **opportunities** often arise during its brown-/greenfield projects?
- Are these **opportunities normally exploited**?
- Do **scope changes** often occur? If yes, what are the **reasons** for and **consequences** of these?
- Do **requirement changes** often occur? If yes, what are the **reasons** for and **consequences** of these?

Project organisation

- Of which roles does the FMCG manufacturer **project organisation** of brown-/greenfield projects exist?
- Which **stakeholders** are important in FMCG manufacturer's brown-/greenfield projects?
- Does FMCG manufacturer often **work with the same partners** in brown-/greenfield projects?
- What are the **pros** of working with the same partners in brown-/greenfield projects?
- What are the **cons** of working with the same partners in brown-/greenfield projects?
- What parts of brown-/greenfield projects does FMCG manufacturer do **internally** and what parts are subcontracted **externally**?
- What are the main **reasons pros and cons** of doing the work **internally?**
- What are the main **reasons, pros and cons** of subcontract the work **externally**?

[1] Capex = Capital expenditure / [2] Opex = Operational expenditure

Information management

- How does FMCG manufacturer manage **information** between the related stakeholders?
- How is the **project's progress** being measured? (meetings, reports, etc.)
- What kind of **progress meetings** are being held normally? (kick-off, mid-term, etc.)
- What kind of **progress reports** are being made normally?

Construction projects of specific FMCG manufacturer with RHDV

- What **kind of collaboration** is there between FMCG manufacturer and RHDHV normally?
- How does FMCG manufacturer manage **information** between FMCG manufacturer and RHDHV?
- What aspects **are not different** when working with RHDHV instead of another engineer?
- What aspects **are different** when working with RHDHV instead of another engineer?
- What are the **pros** and **cons** of working with RHDHV?

Individual case study project

Project drivers

- What were the main **project drivers** of this project?
- What were the **reasons** for these **project drivers**?
- How were the **project drivers** communicated to the stakeholders of the project?

Phasing and timeline

- What were the **phases/steps** of this project?
- What was the **duration** of these phases/steps?
- What was the difference between the **planned time** and the **actual time** of the project?
- What were the **reasons** for and **consequences** of the difference in planned and actual **time**?
- What was the difference between the **planned budget** and the **actual budget** of the project?
- What was the **reasons** for and **consequences** of the difference in planned and actual **budget**?

Problems, challenges and opportunities

- What were the **problems/challenges** FMCG manufacturer faced during this project?
- What **opportunities** arise during this project?
- Did **scope changes** occur? If yes, what were the **reasons** for and **consequences** of these?
- Did **requirement changes** occur? If yes, what were the **reasons** for and **consequences** of these?

Project organisation

- Which **stakeholders** were involved in this project?
- What **kind of collaboration** was there between FMCG manufacturer and the involved stakeholders?
- What were the **problems/challenges** working with these stakeholders in this project?
- How would FMCG manufacturer rate their **satisfactory level** of working with the different stakeholders? (1 to 5, 1 = not satisfied, 3 = neutral, 5 = very satisfied)
- What are the **main reasons** for this **satisfactory level**?

Information management

- How did FMCG manufacturer manage **information** between the related stakeholders?
- How was the **project's progress** being measured? (meetings, reports, etc.)
- What kind of **progress meetings** were being held? (kick-off, mid-term, etc.)
- What kind of **progress reports** were being made?

Project outcome

- How would FMCG manufacturer rate their **satisfactory level** of the project outcome? (1 to 5, 1 = not satisfied, 3 = neutral, 5 = very satisfied)
- What are the **main reasons** for this **satisfactory level**?

Open discussion

Table B-9 - Case study interviews - Interview guide FMCG manufacturer

Data Collection

Appendix C	*Current Situation*	*Exploratory Interviews*
Appendix D	*Current Situation*	*Multiple-Case Study*
Appendix E	*Current Situation*	*Literature Review*
Appendix F	*Current Situation*	*Process Synthesis*
Appendix G	*Transition*	*Literature Review*

(Picture Royal HaskoningDHV, case study project 2A in Russia)

C

Current Situation - Exploratory Interviews

C.1. Process Data

Construction projects from service supplier perspective (i.e. RHDHV)		
Initiation phase	Design phase	Construction phase & Exploitation and maintenance phase
Time		
		• Construction phase can go very fast, if previous phases prepared it well (Exploratory interview, 2nd of May 2018 - 1) • Phase with biggest risk of time overrun (and therefore cost overrun) (Exploratory interview, 7th of May 2018)
Organisation		
	Advantages of design and build contracts: • Parties strengthen each other • No “grey-areas” between different parties Clear roles of different stakeholders: • Responsibilities • Moments • Business models • Contracts • Etc. (Exploratory interview, 2nd of May 2018 - 2) Stakeholder management / engagement is important and generally a problem: • The right stakeholders • At the right moment (Exploratory interview, 27th of March 2018)	Different types of construction organisations: • Construction direction: execution only guided by client • Construction management: execution partly done by client • Different clients have different types of construction organisations (Exploratory interview, 14th of May 2018) • Contractual agreements define construction phase a lot: responsibilities, dependencies, etc. • Importance of focus on contracts/procurement often forgotten by design team • Many obstacles in construction phase caused by bad designing • (Exploratory interview, 14th of May 2018)
Information		
• “What is needed?” (Exploratory interview, 23rd of March 2018) • “Why is what needed?” (Exploratory interview, 7th of May 2018) Risk of losing information due to exchange of information between the initiation and design phase (Exploratory interview, 7th of May 2018)	• “How is it going to be made?” (Exploratory interview, 23rd of March 2018) • Program of requirements (Exploratory interview, 7th of May 2018) Common kick-off and reviews are very important: • Clarity on front-end • Alignment project drivers (as specific and measurable as possible) Design hierarchy approach: • Most important aspects? • Definition of project • Who is going to take care of which aspects? (Exploratory interview, 2nd of May 2018 - 2)	
Integration		
Overall benefits of an integrated way of working: less margins, better knowledge / information exchange, less risks (Exploratory interview, 7th of May 2018)	BIM as integrator: explore possibilities together with contractors (no slack between engineer and contractor) (Exploratory interview, 2nd of May 2018 - 2)	

Table C-1 - Process data - Construction projects from service supplier perspective (Exploratory interviews)

Construction projects in the FMCG manufacturing industry from service supplier perspective (i.e. RHDHV)		
Initiation phase	Design phase	Construction phase / Exploitation & Maintenance phase
Time		
Duration often long, because client thorough study of business case and thinks time can be saved in next phases (Exploratory interview, 2nd of May 2018 - 1) Time as an important project driver: time-to-market is super important (Exploratory interview, 7th of May 2018) Steps of total initiation phase (3-5 months): • Market analysis (volume, growth, competitors, etc.) • Capex [1] cost image (technical concept, process flow diagram, equipment requirements, site availability, etc.) • Opex [2] costs image (operational costs, maintenance, etc.) (Exploratory interview, 8th of May 2018 - 2) Next to time, cost as an important project driver: • High pressure on Capex investments • Follow-up Opex investments • Follow-up Capex investments (extensions, improvements, etc.) • What is needed now, and postponed (Exploratory interview, 7th of May 2018)	Duration normally: • Concept engineering: 10 years • Front-end engineering: 12-18 weeks (Exploratory interview, 27th of March 2018) Planning process equipment difficult: • Contracts awarded as late as possible • Due to procurement department client • Solution: assumptions based on experiences • Life span of process equipment very long, which makes expansions easier than changes (Exploratory interview, 2nd of May 2018 - 1) Time can be saved in design phase if no changes in the initiation phase take place (Exploratory interview, 7th of May 2018)	Problems at the end of the construction phase no direct negative impact on production processes > In many cases the production process can start / continue (Exploratory interview, 2nd of May 2018 - 1) Construction phase consists of: • Civil • Process • Validation (= Commissioning) • Product trail (Exploratory interview, 14th of May 2018) Process of a green- or brownfield project from initiation to exploitation is too long and does not match with the dynamic demands in the FMCG industry (Exploratory interview, 27th of March 2018) Duration (initiation - exploitation) (total: 3 years): • Planning: 1-2 years • Execution: 1-2 years (Exploratory interview, 27th of March 2018)
Organisation		
• Normally done by a non-engineering strategy consultancy, but should be done by engineers (Exploratory interview, 23rd of March 2018) • Important to involve an experienced consultant, because business case development is extremely important (Exploratory interview, 2nd of May 2018 - 1) FMCG manufacturer exists of many different parties and roles: • Sponsor: takes decisions • Project manager: executes project • OpCo [3]: responsibility for production • Maintenance department • Process equipment department (Exploratory interview, 7th of May 2018) Constant trade-off between engineering choices and business choices (Exploratory interview, 27th of March 2018)	Stakeholder management very important, because: • Complex industry • Many stakeholders and parties • Different countries and cultures > Communication problems • Different risks • Not simple engineering problems • Client alignment very important (Exploratory interview, 23rd of March 2018) Projects in developing countries need local partners to get to know the local standards, legislation, etc. (Exploratory interview, 2nd of May 2018 - 1)	Projects in developing countries need more proactive stakeholder management also in construction phase, because construction contractors often unprofessional and unexperienced Disciplines of a factory: • Building (water resistance) • Utilities (water, electricity, power, heating, cooling, etc.) • Production equipment • Logistics (raw materials > finished products, personnel, transportation, etc.) Collaboration between disciplines: • Process equipment has to be delivered, while construction is not finished yet Collaboration even more important at brownfield projects > Extra stakeholder: OpCo factory / plant (Exploratory interview, 2nd of May 2018 - 1)
Information		
Involve all stakeholders for information exchange already in initiation phase (Exploratory interview, 7th of May 2018) Questions to be asked: • How much to produce? What to produce? How to produce? • Knowledge on content is important to help client to make the right decisions (Exploratory interview, 8th of May 2018 - 2)	• Information about certain assets (e.g. process equipment) only when contracts are awarded • What level of detail of information is needed at which point in the design phase? (Exploratory interview, 8th of May 2018 - 1)	Building meets different standards in different sectors of FMCG: • Pharmaceuticals: building very important, because of high quality standards • Others: building just a “shell” (Exploratory interview, 2nd of May 2018 - 1) 3 validation steps in FMCG industry • FAT: Factory Acceptance Test • SAT: Site Acceptance Test • SIT: Site Integration Test (Exploratory interview, 14th of May 2018)
Changeability		
Changes in demands: • Little changes in product specification > Difficult to change • A lot of changes in volumes and packaging > Easy to change (extra lines, etc.) • Changeability taken into account when choosing masterplan location and making masterplan layout (Exploratory interview, 2nd of May 2018 - 1) Changeability often not an important project driver: • Initial investment as low as possible • Changeability often costs more money (Exploratory interview, 7th of May 2018) • Currently: no changeable business case > Desired: changeable business case and only less changeability after procurement • Take continuously changing market-demands into account in business case (Exploratory interview, 8th of May 2018 - 2)	Little changeability in design phase > Changes from initiation phases > Cost- and time overrun (Exploratory interview, 7th of May 2018) More changeability by: • Automatization of design (e.g. parametric design) • Define the latest moment (before procurement?) when changes are still possible • Building an ecosystem around client with all suppliers > Identify and manage all relevant suppliers (Exploratory interview, 8th of May 2018 - 1) Life span of process equipment very long, which makes expansions easier than changes (Exploratory interview, 2nd of May 2018 - 1)	• Uncertainty, because of continuous changes > Stress > Non-optimal processes • Main demand changes > Scope change plants / factories > Often not possible (Exploratory interview, 27th of March 2018) Examples of non-changeable assets: • Production processes with gravity and therefore towers • Utilities production processes • Size of site/masterplan • Different zones in factories: high care / low care, wet / dry, etc. (Exploratory interview, 27th of March 2018)

Integration		
Changeability is integrating: disciplines, volumes and market demands (Exploratory interview, 8th of May 2018 - 2) Technologies currently used integration: • NL: BIM • Emerging countries: AutoCAD/Printed drawings • Technologies for the future used for integration: web-based, data mining, digital factory, etc. (Exploratory interview, 23rd of March 2018)	No Babylon-effect: • No small pieces to consultants/contractors • One consultant/engineer that serves as integrator (Exploratory interview, 23rd of March 2018)	• Design to construct: On paper design can seems integrated, but when contracted / procured divided into small pieces and not integrated anymore • Make sure hand-over from design to procurement and construction integration does not get lost (Exploratory interview, 23rd of March 2018)

[1] *Capex = Capital expenditure*
[2] *Opex = Operational expenditure*
[3] *OpCo = Operational company*

Table C-2 - Process data - Construction projects in the FMCG manufacturing industry from service supplier perspective (Exploratory interviews)

Key take-aways construction projects in the FMCG manufacturing industry from service supplier perspective (i.e. RHDHV)	
Exploratory interview	Key take-aways

I-1 (Exploratory interview, 2nd of May 2018 - 1)	Importance of:
	• Initiation phase with decisions made based on facts and research
	  ○ Stakeholders aligned (clear arrangements and perspectives on the projects)
	  ○ Right budget
	• Proactive project management in developing countries
	  ○ Local partners
	  ○ Translation to local standards

I-2 (Exploratory interview, 14th of May 2018)	Importance of: • Clear project drivers ○ Clear: communicated, delineated, measurable • Good kick-off • Good reviews • Good contract management
I-3 (Exploratory interview, 2nd of May 2018 - 2)	Biggest problems are: • Not an integrated approach of the whole process from initiation to exploitation (no general contractor as design and builder) • Design hierarchy / project drivers not clear • Stakeholder management

I-4 (Exploratory interview, 27th of March 2018)	Biggest problems are:
	• Stakeholder management (right stakeholders at the right moment)
	• FMCG:
	  ○ Process from initiation to exploitation too long and does not match dynamic demands
	  ▪ Uncertainty
	  ▪ Over specification
	  ○ Assets in FMCG factories inflexible and do not match dynamic demands

I-5 (Exploratory interview, 8th of May 2018 - 1)	Importance of: • During design phase, determine which information (which detail level of information) is necessary at which moment • Different stakes at different moments of stakeholders
I-6 (Exploratory interview, 23rd of March 2018)	Biggest problems are: • Stakeholder management (complexity industry, many stakeholders, geographical differences) • Interface management
I-7 (Exploratory interview, 7th of May 2018)	Importance of: • Margins of products produced in factories determine the process of designing and building the factory • Biggest risks (linked to budget and schedule) in construction, but biggest impact on reducing these risks can be made in initiation and design phases • FMCG manufacturer cannot be seen as one single actor, but consists of many actors • Determine which aspects of the design assignment should be changeable, and which are static
I-8 (Exploratory interview, 8th of May 2018 - 2)	Biggest problems are: • Changeability of construction project is minimal after planning and budget are made based on the business case • However, actually the changeability of the construction project should only be minimal after the procurement phase the

Table C-3 - Process data - Key take-aways construction projects in the FMCG manufacturing industry from service supplier perspective (Exploratory interviews)

D

Current Situation - Multiple-Case Study

D.1. Data FMCG Manufacturers

Data FMCG manufacturers			
	FMCG manufacturer 1	FMCG manufacturer 2	FMCG manufacturer 3
General			
Founded	19th century	19th century	2008 (latest merge)
Country headquarter	Netherlands	USA	Belgium
Ownership			
Market	Beverages	Consumer goods	Beverages
Stock listed / Legal status	Family owned	Stock listed	Stock listed
Organisational structure			
Number of geographic zones	4	5	9
Geographic zones	Africa, Middle East and Eastern Europe / Americas / Asia Pacific / Europe	Asia / Central & Eastern Europe, Middle East and Africa (CEEMEA), Latin America, North America, Western Europe	Africa, APAC North, APAC South, Europe, Latin America COPEC, Latin America North, Latin America South, Middle Americas, North America
Product portfolio			
Number of categories	1	10	1
Categories	Alcoholic beverages / Non-alcoholic beverages	Baby / Feminine care / Family / Fabric / Home / Hair / Skin & Personal care / Grooming / Oral / Personal health care	Alcoholic beverages / Non-alcoholic beverages
Number of different brands	> 300	29 Top brands / 66 All brands	> 500
Number of countries brands sold	190	> 180	> 100
Plants			
Number of production plants worldwide	174	135	177
Projects			
Number of production plants with RHDHV projects	70		4

Table D-1 - Data FMCG manufacturers (Annual reports FMCG manufacturers)

D.2. General Data Projects

General data projects							
General information							
Project reference	1A.1 - Ethiopia (Phase 1)	1A.3 - Ethiopia (Phase 2)	1A.3 - Ethiopia (Phase 3)	1B - Vietnam	2A - Russia	2B - Pakistan	3 - Nigeria
Project information - FMCG Manufacturer							
Type	Brewery			Brewery	Production plant	Production plant	Brewery
Project size FMCG manufacturer	€110 million	€95 million		€160 million			€215 million
Old/new surface Old/new capacity	Old: 0 m^2 New: 1,5 million hl/year			Old: 0,5 million hl/year New: 6,0 million hl/year	New: 8,000 m^2	New: 15,000 m^2	Old: 0 m^2 New: 50,000 m^2 New: 3,2 million hl/year
Green-/brownfield	Greenfield	Brownfield	Brownfield	Brownfield	Brownfield	Brownfield	Greenfield
Project information - Service supplier (i.e. RHDHV)							
Involvement in project phases	Design and construction	Initiation, design and construction	Initiation, design and construction	Design and construction	Design	Design and construction	Design and construction
Service (Eng. Proc. Constr. manag.)	EPCm	EPCm	EPCm	EPCm	EP	EPCm	EPCm
Ended / Ongoing	Ended	Ended	Ongoing	Ongoing	Ended	Ongoing	Ongoing
Duration (weeks) (until 2018 Week 24)	257	147	68	114	63	13	70

Table D-2 - General data projects (Project documentation)

Location data projects					
Geographical location project					
Continent	Africa	Asia	Europe	Asia	Africa
Country	Ethiopia	Vietnam	Russia	Pakistan	Nigeria
Country specific information					
Population	102,4 million (2016)	92,7 million (2016)	144,3 million (2016)	193,2 million (2016)	154,5 million (2009)
Population density	101/km² (2016)	283/km² (2016)	9/km² (2016)	264/km² (2016)	212/km² (2016)
GDP nominal - Total	72,37 milliard USD (2016)	202,6 milliard USD (2016)	1,283 billion USD (2016)	283,7 milliard USD (2016)	405,1 milliard USD (2016)
GDP nominal - Per capita	706,76 USD (2016)	2.185,69 USD (2016)	8.748,36 USD (2016)	1.468,19 USD (2016)	2.177,99 USD (2016)
Currency	Ethiopian birr (Br)	Vietnamese đồng (₫)	Russian ruble (₽)	Pakistani rupee (Rs)	Nigerian naira (₦)

Table D-3 - General data projects - Location data projects (Project documentation)

D.3. Output Data Projects

Work breakdowns service supplier (i.e. RHDHV)						
1A.1 - Ethiopia	1A.2 - Ethiopia	1A.3 - Ethiopia	1B - Vietnam	2A - Russia	2B - Pakistan	3 - Nigeria
General site layout	Packaging hall	Demolition works		Site layout and logistics study	Design review disciplines	A) Civil works: • External works (land levelling, roads, drainage) • Foundations works • Structural works in concrete or steel • Final finishes and outfitting
Production	Full product store	Silo block		Line relocations	Architectural	
Utilities, WTP [1] and soda	Spare part storage	Malt intake		New operations building (8000 m^2)	Structural	
General store and workshop	Substations	Brewhouse		Relocation of existing pipe rack	Mechanical - Utilities	
Filling and full product store	General store	Water plant and storage		Tank farm	Mechanical - HVAC [7]	B) MEP [8] works: • Mechanical (air-conditioning, mechanical air supply and ventilation) • Electrical (power, lighting, socket outlets, street lighting, earthing, transformer) • Electronic (LAN, Telephone, BMS, access control) • Plumbing (water for toilets, showers, sewage) • Fire (sprinkler, hoses, alarm, pump, fire water tank)
Power house	Balcony	Cellar		Refurbishment of building	Fire	
Pipe bridge	Raw material intake	Utility building		Permitting	Electrical lead	
	Brew house	Corridor				C) Process equipment: • Storage tanks, brewery equipment, filling and packing lines • Water treatment plant (WWTP not part of scope service supplier)
	FST's [2]	FPS [5]				
	BBT's [3]	Packaging hall				
	Engine room	Packaging support block				
	Pipe bridge	Power plant				
	Buffer tank fire fighting	Garage				
	WWTT [4]	Pipe bridge (external)				
		Pipe bridge (internal)				
		Amenities				
		WWTP				
		Gate house and security				
		M&E [6] works buildings				
		M&E works site				
		External works				

[1] WTP = Water treatment plant

[2] FTS = Fermentation temperature system
[3] BBT = Bright beer tank
[4] WWTT = Waste water treatment plant

[5] FPS = Full product store
[6] M&E = Manufacturing and engineering

[7] HVAC = Heating, ventilation and air conditioning

[8] MEP = Mechanical, electrical, plumbing

Table D-4 - Output data projects - Work breakdowns service supplier (Project documentation)

Billed work breakdowns service supplier (i.e. RHDHV)						
1A.1 - Ethiopia	1A.2 - Ethiopia	1A.3 - Ethiopia	1B - Vietnam	2A - Russia	2B - Pakistan	3 - Nigeria
Post tender adjustments	Architectural	Extra work PM	3D render work	BD [11] Engineering	Proposal	Integration
A0 - Proposals	Construction management	Extra work Technical	CAD layout	BD Project Management	Phase 2 - Civil	Integration - Advice laboratories
A2 - Architecture (Prelim [1])	Design coordinator	DD / FC - Architectural	Civil integration activities	BD Reimbursable	Phase 2 - LEED [15]	Integration - Review utilities and furniture
A2 - Preliminary Design	Infra civil	DD / FC - Civil infra	Concept	BD 16m change	Phase 2 - Other Experts	Proposal - Project management integration
A3 - Structure (Prelim)	CM - Invoicing	DD / FC - MEP	ICA [10] - Support	CD [12] Design Management	Phase 2 - Project Management	Proposal - Construction management
A4 - M&E (Prelim)	Developed design / Construction design	DD / FC - Project management	PDB	CD EIA [13]	Project Management	
A5 - Civil (Prelim)	Office backup	DD / FC - Structural	Proposal	CD Mechanical	Architect	
A7 - Additional works (Prelim)	PD [4] - Arch [5]	DD / FC - Site visits	Virtual reality testing and advice	CD Process Utilities	Civil	
A8 - Project management (Prelim)	PD - Civil infra	Earth works - Engineering		CD Project Management	Drafter / Modeller	
Architecture	PD - MEP	Meeting general	*[10] ICA = Intercompany agreement*	CD Reimbursable	Electrical	
B3 - Structure (Tender)	PD - PM	PD - Architectural		CD Structural	Expenses	
B5 - Civil (Tender)	PD - Structural	PD - MEP		MP Engineering	HVAC	
Civil (review)	Tender	PD - Project management		MP Project management	LEED	
CM [2] team expats	Ext - Earth Works & PDB [6]	PD - Structural		PC [14] Project Management	Mechanical	
CM team locals	Ext - Engineering	PDB - Engineering		PC Reimbursable	Experts	
D2 - Architecture	Ext - MP [7] - Invoice	Tender - Project management		Procurement	Structural	
E2 - Site visits	Ext - MP - Masterplan	Tender - Technical		Site visit		
F3 - Home office back-up	Ext - MP - Spending	Proposal				
M&E (review) (RHDHV UK)	PDB					
M&E (RHDHV UK)	Earth Works - Engineering					
PM [3] site visits	Phase II - Contingency					
Post tender adjustments	Review - Subcontractor					
Project management	Landslide					
RHDHV Vietnam	PM					
Site visits	PM DD [8] / FC [9]					
Structure	Review RHDHV Vietnam					
Structure (review)	Site visits					
Utilities	Structural					
	Technical					

[1] Prelim = Preliminary
[2] CM = Construction management
[3] PM = Project management
[4] PD = Preliminary design
[5] Arch = Architectural
[6] PDB = Project data book
[7] MP = Masterplan
[8] DD = Detailed design
[9] FC = For construction
[10] ICA = Intercompany agreement
[12] CD = Concept design
[13] EIA = Environmental impact assessment
[14] PC = Procurement
[15] LEED = Leadership in energy and environmental design

Table D-5 - Output data projects - Billed work breakdowns service supplier (Project documentation)

Billed work breakdowns in % of total costs manhours service supplier (i.e. RHDHV) for FMCG manufacturers									
1A.1 - Ethiopia		1B - Vietnam		2A - Russia		2B - Pakistan		3 - Nigeria	
Billed work breakdown	% *	Billed work breakdown	%	Billed work breakdown	%	Billed work breakdown	%	Billed work breakdown	%
Proposal	0,57 %	Proposal	0,83 %	BD [1]	9,98 %	Proposal	3,31 %	Proposal	23,67 %
PD	14,53 %	CD	8,40 %	CD [2]	47,12 %			Integration	53,18 %
CM	33,77 %	PDB	4,37 %	MP [3]	13,03 %			CM	23,64 %
1A.2 - Ethiopia		ICA - Support	33,42 %	PC [4]	18,48 %				
PDB	1,38 %	Civil integration activities	36,98 %						
M	2,49 %								
PD	23,35 %								
CM	20,47 %								
1A.3 - Ethiopia									
Proposal	1,71 %								
DD/FC	41,42 %								
PD	35,35 %								
PDB	1,00 %								
Tender	5,69 %								

[1] BD = Basic design
[2] CD = Concept design
[3] MP = Master plan
[4] PC = Procurement

** % of total costs manhours service supplier (i.e. RHDHV) for FMCG manufacturer*

Table D-6 - Output data projects - Billed work breakdowns in % of total costs manhours service supplier for FMCG manufacturers (Project documentation)

Tender packages (TP) *				
1A.1 - Ethiopia	1A.3 - Ethiopia	1A.3 - Ethiopia	2A - Russia	2B - Pakistan
TP1 - Earth works	TP1 - Site clearings and earth work		TP1 - General contractor	Foundation works - Including site setup activities that will facilitate the works of general contractor
TP2 - Pre-engineered building (PEB)	TP2 - Pre-engineered building (PEB)		TP2 - Civil & MEP	
TP3 - Early foundation works	TP3 - Foundation works		TP3 - TP 6	Full general contractor - Including civil, installation of pre-engineered metal building (PEMB), architecture, mechanical, electrical, plumbing etc.
TP4 - Main civil works (Arch / M&E)	TP4 - Main civil works		TP7 - General specification for construction works	
	TP5 - Acid resistant floor tiles		TP5	

** Information not available for projects: 1B & 3*

Table D-7 - Output data projects - Tender packages (Project documentation)

Need of standardisation of output of construction projects of different FMCG manufacturers		
FMCG manufacturer 1	FMCG manufacturer 2	FMCG manufacturer 3
FMCG manufacturer perspective		
• Standard breweries as goal, because of lower Capex (capital expenditure) investments • Standardised parts into detail: packaging line, utilities, standard buildings (PEB), etc. • Little standards for greenfield breweries (Case study interview, 27th of June 2018)	• Simplification and standardisation of the outcome of projects would be very valuable from a project management point of view • Processes in productions units are a lot less standard than processes in warehouses/dc's • FMCG manufacturer's long history with merges and take-overs causes less standardised sites and factories • Production lines are standardised over the whole globe • For all parts of the production lines a standard process supplier (Case study interview, 12th of June 2018)	• Generally, well standardised but adapted to regional brands • On global brands there is no compromise - standards apply rigidly, but for regional brands specific variations from standardised approach (Case study interview, 19th of July 2018)
Service supplier perspective (i.e. RHDHV)		
• Sites standardised: usually only one entrance and exit, for security reasons • Logistic process (from raw materials to finished goods) and layout of general breweries are standardised • Standardised packaging materials: glass, cans • Standardised glass bottles logistical process: Depalletize > One-way/returnable > Palletiser (Case study interview, 13th of June 2018; Case study interview, 14th of June 2018)	Standard Distribution Centres (SDC's) are very standard (Case study interview, 15th of June 2018 - 2)	• Brewing process is similar everywhere, therefore plants same logistics (Case study interview, 19th of June 2018) • All suppliers sitting in their own little box and requiring process water / utilities / etc. • Volumes of product water (filtered raw water) and process water (slightly less filtered than product water) needed for different parts of the process equipment are standard • Important decisions are made based on modelling, but only for sure if everything works when the brewery is in full production (Case study interview, 27th of June 2018)

Table D-8 - Output data projects - Need of standardisation of output of construction projects of different FMCG manufacturers (Case study interviews)

D.4. Process Data Projects

D.4.1. Phases and Durations

Phases and durations of FMCG manufacturers		
FMCG manufacturer 1	FMCG manufacturer 2	FMCG manufacturer 3
• Duration engineering: generally around 6 months • Duration earth works: differs a lot per project (Case study interview, 27th of June 2018) • Construction small brewery should be possible within a year (Case study interview, 18th of June) • First pile - First brew: 12 months • Conceptual Design - First brew: 2 year • Total duration project from idea till first brew: 2,5 - 3 years (Case study interview, 18th of June)	• Start - Commitment budget and schedule: 6 months • Start - Completion design and construction: 12-16 months (Case study interview, 12th of June 2018)	Construction phase: shortest duration of three observed FMCG manufacturers (Case study interview, 4th of June 2018)

Table D-9 - Process data projects - Phases and durations projects of FMCG manufacturers (Case study interviews)

Phases and durations projects from service supplier (i.e. RHDHV) perspective *									
1A.1 - Ethiopia		1A.3 - Ethiopia		1A.3 - Ethiopia		2A - Russia		2B - Pakistan	
Start									
Prelim engineering and MEP	61	Basic engineering (civil)	83	Masterplan development and approval	94	Masterplan study	10	Start	36
Final design and tender	70	Earth works	125	PDB and approval	68	Conceptual design	30	Funding	122
Tender main civil contract	35	Pre-engineered building system	290	Fund approval	40	1st phase conceptual design	15	Sourcing	191
Application building permit	19	Preliminary design civil	100	Engineering earth works (TP1)	117	2nd phase conceptual design	15	Main works enquiry	116
Start construction main civil contract	221	Detail / tender documents for main foundation works and WWTP	248	Award and Start Construction	160	Stage	60	Design	191
Start process machinery installations	160	Detail / tender documents for main civil works	343	Civil preliminary design and MEP	125	Permit	60	Foundation PO [1]	56
		Process installations suppliers	371	Pre-engineered building (PEB) (TP2)	298	Procurement	160	Engineering and design	236
				Foundation works detail engineering (TP3)	270			Phase 1	30
				Main civil works engineering (TP4)	335	[1] PO = Production order		Phase 2	45
				Acid resistant tiling works	185	[2] SOP = Standard operating procedure		Equipment delivery	370
				PM	424			Construction	476
								Check steel structure conditions	175
								Foundation construction	84
								Main scope construction	235
								SOP [2]	115
End									
Total days	555	Total days	481	Total days	598	Total days	553	Total days	798
Total months	18	Total months	15	Total months	19	Total months	18	Total months	26

** Information not available for projects: 1B & 3*

Table D-10 - Process data projects - Phases and durations projects service supplier (Project documentation)

Phases and durations projects from FMCG manufacturer and service supplier (i.e. RHDHV) perspective				
1A - Ethiopia	1B - Vietnam	2A - Russia	2B - Pakistan	3
Phases				
FMCG manufacturer • Business case investigation • Masterplan location > Water available? • Fund approval from global board? • Management service and product suppliers (Case study interview, 14th of June 2018) Service supplier • Masterplan layout • Preliminary design, engineering, etc. • Construction management and supervision (Case study interview, 14th of June 2018)	Service supplier • Project data book (PDB) • Project design: civil in broad view: lightning, roads, water, fences, camera's, etc. • Project execution: construction management and supervision (Case study interview, 13th of June 2018)	Service supplier • Initiation: workshop to challenge initial idea of FMCG manufacturer • Design: civil design including process design, until application building permit • Procurement: market analysis of contractors, contractor selection • Project on-hold: project did not yet go into construction, because business case was not valid at that moment (Case study interview, 15th of June 2018 - 2)	Service supplier 1 • Front-end 1: initiation and design - 1 • Procurement • Project on-hold (Case study interview, 6th of June 2018) Service supplier 2 (i.e. RHDHV) • Front-end 2: initiation and design - 2 • Design review and update • Procurement • Project on-hold (Case study interview, 6th of June 2018)	FMCG manufacturer 1. Development concept 2. Detailed engineering 3. Implementation 4. In operation 5. Close out (Case study interview, 19th of July 2018) Service supplier • Construction management and supervision • Equipment integration (Case study interview, 4th of June 2018)
Durations				
• Phase 2: Planned to start in 2018, but started beginning 2015 (Case study interview, 14th of June 2018) • Phase 3: Delay with product suppliers in the construction phase led to + 0,5 year in the construction phase (Case study interview, 15th of June 2018 - 1)	• Construction (first pole - first brew): 14 months (Case study interview, 18th of June) • Project execution had to go very fast, because the money is now reserved/spent (Case study interview, 13th of June 2018) • Commissioning December 2019: in PDB PM in FMCG manufacturer, but in reality, probably sooner (not communicated within global management to avoid pressure) (Case study interview, 18th of June)	• Concept phase: Planned 6 weeks, actual + 3 weeks (Case study interview, 15th of June 2018 - 2)	• No time overrun yet (Case study interview, 6th of June 2018)	FMCG manufacturer Continuously 1. 1 year in parallel to implementation 2. 14 months construction 3. 3 months ramp up 4. 3 months close out (some of these overlapped) (Case study interview, 19th of July 2018) • Initial plan was met, no variance - although 3 months loss due to EIA, able to make most of time up (Case study interview, 19th of July 2018) Service supplier • June 2017: main contracts/blocks were awarded > No contract for design of pipe bridge, which integrates the whole brewery • July/August 2017: service supplier awarded for designing the pipe bridge > Making sure that the connection between the different process blocks were compatible o No civil integration > No details of the process suppliers • August/September 2017: concerns about progress, because of incomplete information of suppliers • November 2017: good progress with the design of the pipe bridge (Case study interview, 27th of June 2018) • After initiation and design project on-hold because there was a merge (Case study interview, 4th of June 2018) • Fastest project ever for service supplier: construction in less than 1 year (Case study interview, 4th of June 2018) • Slow conceptual development (no real intention to implement project), led to very fast construction phase (Case study interview, 27th of June 2018) • First brew was only delayed by 4 days, but final finish of all construction works is 1-2 month late (Case study interview, 19th of June 2018)

Table D-11 - Process data projects - Phases and durations from FMCG manufacturer and service supplier perspective (Case study interviews)

D.4.2. Information Management

Information management in process of construction projects of different FMCG manufacturers		
FMCG manufacturer 1	FMCG manufacturer 2	FMCG manufacturer 3
Information management to steering group from PM: • Monthly: financial • 2 months: pictures • Officially every supplier (service and product) should also hand in monthly reports (Case study interview, 27th of June 2018) Physical steering group meetings: • 3 times a year • PM goes to site when one of the main stakeholders goes > Regional manager: 2 times a year > Chairman: year • Only extra meetings in crisis situations > Many stakeholders in steering group also participate in other steering groups of other projects (Case study interview, 27th of June 2018) • Ideally: Service supplier <> FMCG manufacturer <> OpCo Reality: FMCG manufacturer <> Service supplier <> OpCo • Closer to construction phase > More contact with OpCo (Case study interview, 15th of June 2018 - 1) Communication: • Communication Service supplier - FMCG manufacturer: planning, budget, etc. • Communication Service supplier - Process product supplier: partly via FMCG manufacturer • Communication Service supplier - Civil product supplier: completely via service supplier > Pro long-term collaboration is suppliers communicating with each other > Tenders via service supplier, contracts via FMCG manufacturer, execution via service supplier • Communication Suppliers - FMCG manufacturer procurement: everything concerning claims (civil or process) • Communication OpCo - FMCG manufacturer project organisation: change orders, over-work, etc. (Case study interview, 27th of June 2018) • SharePoint data base with document manager • Service supplier gets 3D models of all suppliers to integrate design > Clash detection > Better way of integrating, availability trustable data (Case study interview, 18th of June)	Information flows • Process Supplier > Project Manager Process > Project Manager Facility > Facility Designer (e.g. RHDHV) • Facility Supplier > Project Manager Facility > Project Manager Process > Process Designer (Case study interview, 12th of June 2018)	• Legal department: corporate affairs, statutory and government related matters • Contracts administration: communication with all suppliers (Case study interview, 19th of July 2018) • Project progress meetings: daily or weekly and monthly progress reports • Progress reports: for top projects weekly 1-pager shared with global management • Project meetings: starting kick-off, regular design meetings, regular site visits, weekly discipline meetings (Case study interview, 19th of July 2018) • Online collaboration tool for reporting, planning, permit applications, etc. > Very smooth process, more transparent and faster (real-time) (Case study interview, 19th of July 2018)

Table D-12 - Process data projects - Information management in process of construction projects of different FMCG manufacturers (Case study interviews)

D.4.3. Problems Current Process

Root causes poor project process in the perspective of one or more actors in the project organisation

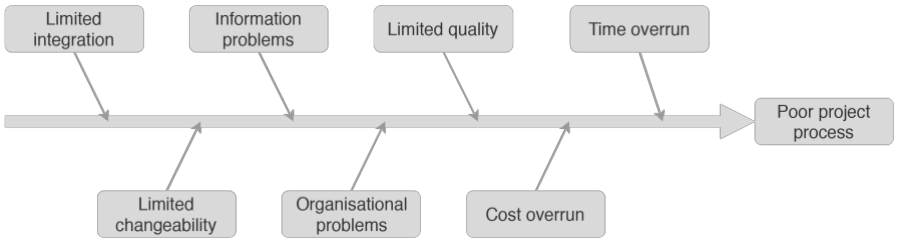

Figure D-1 - Problems current process - Root causes poor project process (Case study interviews)

Root causes time overrun

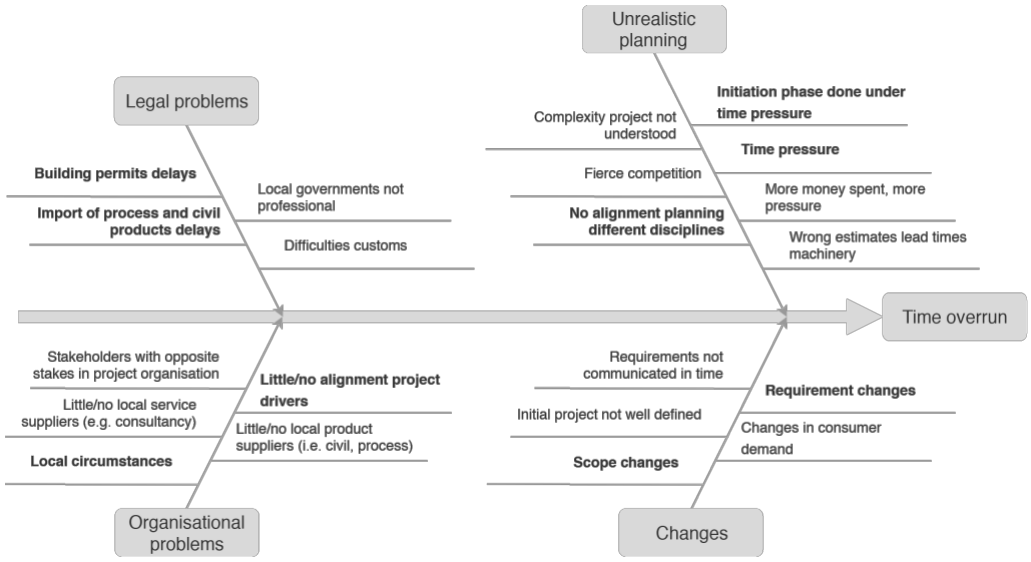

Figure D-2 - Problems current process - Root causes time overrun (Case study interviews)

Root causes cost overrun

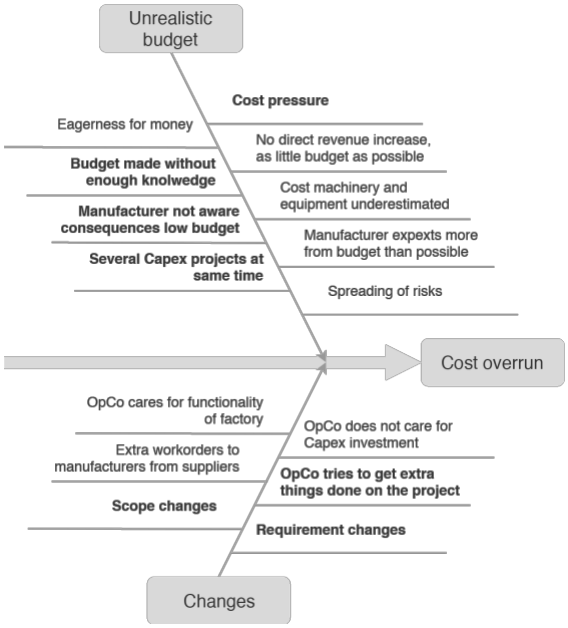

Figure D-3 - Problems current process - Root causes cost overrun (Case study interviews)

Root causes limited quality

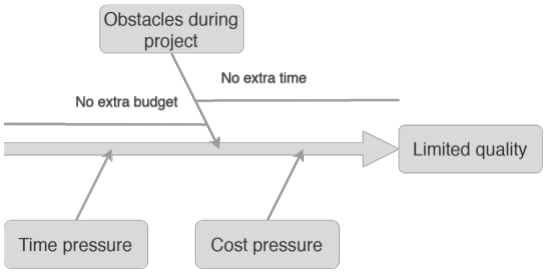

Figure D-4 - Problems current process - Root causes limited quality (Case study interviews)

Root causes organisational problems

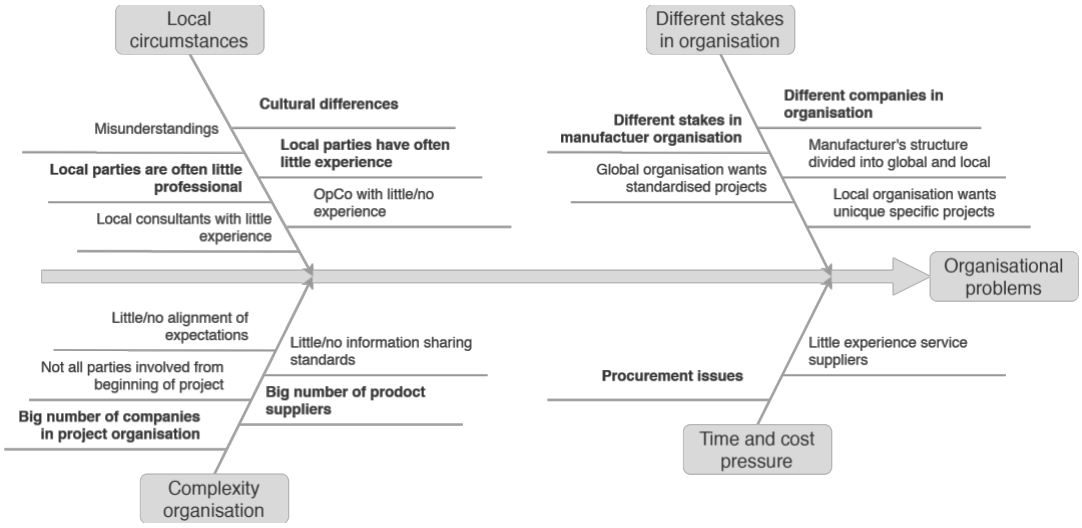

Figure D-5 - Problems current process - Root causes organisational problems (Case study interviews)

Root causes information problems

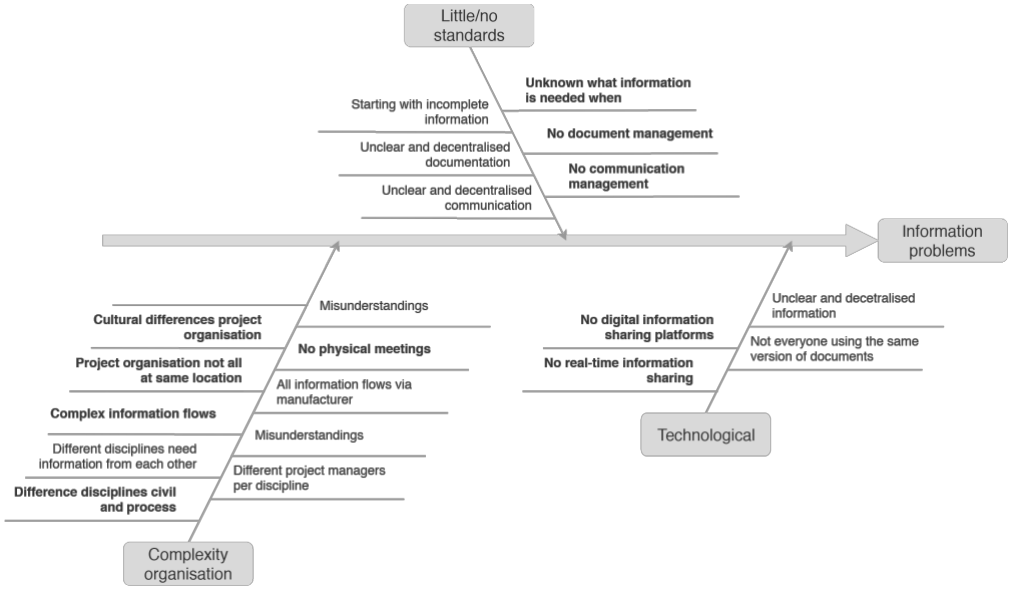

Figure D-6 - Problems current process - Root causes information problems (Case study interviews)

Root causes limited changeability

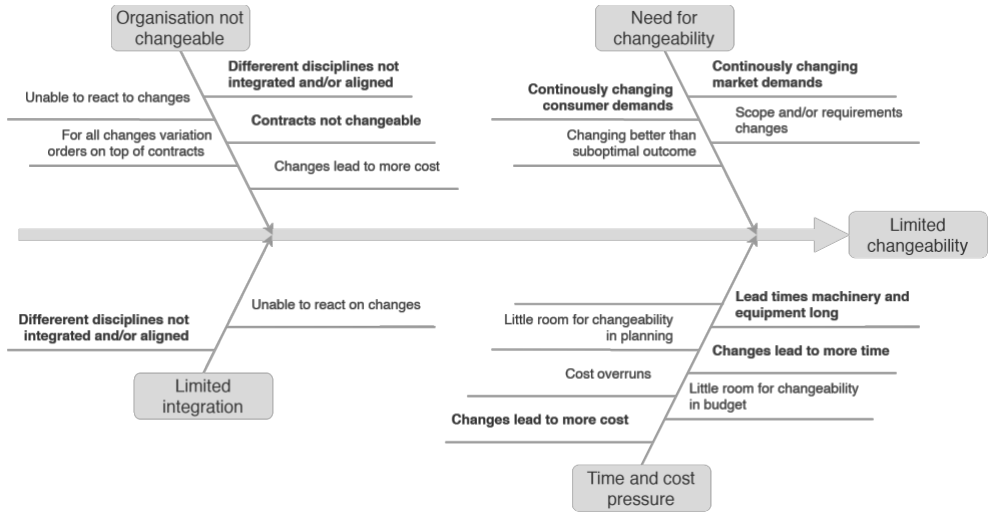

Figure D-7 - Problems current process - Root causes limited changeability (Case study interviews)

Root causes limited integration

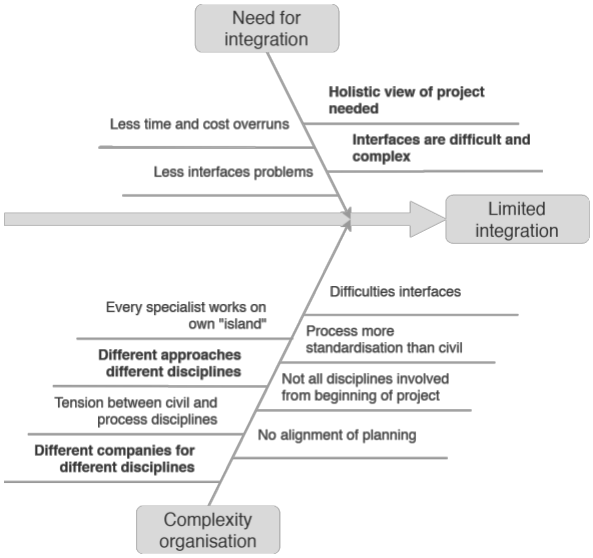

Figure D-8 - Problems and current process - Root causes limited integration (Case study interviews)

Summary problems current processes projects
FMCG manufacturer 1 - Case study project 1A in Ethiopia

General
• Phases were planned to be a lot less close to each other, but due to the rapidly increasing demand the phases were executed directly after/during each other
• Problems and challenges became less/different in phase 2 and phase 3, because the long-term collaboration made all parties learn from each other
 	
Phase 1 (1A.1)
• Budget and schedule too tight, because of unrealistic assumptions by the FMCG manufacturer (observation from service supplier perspective) which led to different consequences:
  o Less quality
  o Less changeability: site too small, no room or measures for possible extensions
• Challenges local contractor, due to cultural differences and little experience:
  o Local contractor did not keep up the pace of the project
  o Local contractor looked differently at deadlines and did not take them as strict as the FMCG manufacturer and service supplier
 	
Phase 2 (1A.2)
• More experienced and professional contractors led to more quality and easier management
• Operational company of the brewery as an extra stakeholder
 	
Phase 3 (1A.3)
• Difficulties with the operational company, because the project site was site is too small
• Project site too small because of the tight budget in phase 1
• Delays due to product suppliers and legal issues
• Planning issues between disciplines civil and process, caused by limited integration

FMCG manufacturer 1 - Case study project 1B in Vietnam
• Local department of FMCG manufacturer is a very developed and professional client for a development country in an emerging market • Project is very cheap for the FMCG manufacturer, because of the cheap way of working of the service supplier • Process engineering fully done by the FMCG manufacturer and civil engineering fully done by the service supplier, causes tension between process and civil disciplines; • Tension between FMCG manufacturer and service supplier, because project schedule and budget are too tight • Quality of local department service supplier not as high as “global” department of service supplier
FMCG manufacturer 2 - Case study project 2A in Russia
• Cultural differences between “global” department of service supplier and local department of service supplier were challenging • Delivering of quality by local department of service supplier was challenging • The contractor supplier market was unknown so had to be analysed and researched • Collaboration with operational company was challenging • Little intra-collaboration in the project organisation of FMCG manufacturer, services supplier had to facilitate better collaboration by organising workshops, etc. • Project on-hold after procurement phase (products not yet procured), due to feedback loop to the business case

FMCG manufacturer 2 - Case study project 2B in Pakistan
• In 2014 project on-hold after procurement phase (civil products already on site), after being engineered by service supplier 1 • Procurement of civil products before final go/no-go happened, because that was only a small part of the whole project budget • In the beginning of 2018 the project continues with a different service supplier (2) (i.e. RHDHV) conducting a design review of the 2014 design, because the FMCG manufacturer was not satisfied with the first design • Collaboration between service supplier 2 and local service supplier was challenging • Information provision from FMCG manufacturer was challenging • In august 2018, project on-hold after design review (no new products procured), due to feedback loop to the business case
FMCG manufacturer 3 - Case study project 3 in Nigeria
• Fastest project ever done by specific service supplier (i.e. RHDHV) (construction in less than a year), because of extremely strict management by FMCG manufacturer • Service supplier for construction management and process integration • Safety regulations and standards of FMCG manufacturer very high • Cultural differences with local subcontractors challenging • Legal challenges: building permit approval, approval for selling the beer • Information exchange went very smoothly due to online collaboration tools

Table D-13 - Problems and current process - Summary problems current processes projects (Project documentation & Case study interviews)

E

Current Situation - Literature Review

E.1. Output Data

E.1.1. Spatial Requirements

Phasing factors determining spatial requirements			
Phase 1	Phase 2	Phase 3	Phase 4
Preliminary study of all location factors	Design masterplan	Design surfaces (length and width)	Define construction methods
Study different engineering methods	Plan underground facilities (e.g. piping, foundation)	Design heights (ceiling heights and number of stories)	Define materials
Study standard building types			Define contracting methods
Plan before buying site	Design functional future use	Define floor loads and design column plan	
Plan for expansion			

Table E-1 - Spatial requirements - Phasing factors determining spatial requirements (Noyes, 1919)

Dimensions of manufacturing facility layout		
Manufacturing system	Layout configurations	Facility shapes
• Product layout • Cellular layout • Process layout • Fixed product layout	• Single row • Multi-rows • Loop layout • Open field 	• Regular shapes • Irregular shapes
Constraints	Resolution approaches	Layout objectives
• Area constraints (space and facilities) • Positioning constraints (clearance between facilities, orientation, etc.) • Budget constraints	• Dynamic programming • Construction and improvements	• Min space costs • Min handling costs • Min rearrangement costs • Min shape irregularities • Min backtracking and bypassing

Table E-2 - Spatial requirements - Dimensions of manufacturing facility layout (Drira et al., 2006)

Factors for standardisation	
Products and components	Processes and procedures
Standard building products	Standard forms of contracts
Standard buildings	Standard processes, procedures and techniques
Standard design, details or specification	Use of same team and network
Similar solutions on different locations	Centralised purchasing and specification
Pre-fab (as little on site as possible)	Interchangeability
Quality assured, factory built	Total building package (fewer suppliers)

Table E-3 - Spatial requirements - Factors for standardisation (Gibb & Isack, 2001)

E.2. Process Data

E.2.1. Phases and Durations

Phases and durations						
Start drawing plans	Final decision to build	Start of external financing	Completion of external financing	Placing first order	Start of construction	Completion of construction
1 months	2 months	1 month	1 month	2 months	15 months	
7 months						
Total: 22 months						

Table E-4 - Phases and durations (Mayer, 1960)

Phases and deliverables for construction projects in the manufacturing industry			
Initiation		Design	
General			
Business idea	Site location	Concept design	Detailed design
Business case	Masterplan	Process design	Project execution plan
Team dynamics	Alternatives analysis		
Specific			
Business case	Alternatives analysis	Site status	
• Market analysis • Competition analysis • Capex [1] and Opex [2] analysis • Legal/regulatory framework • Business plan	• Competitive technology selection • Business objectives statement	• Site determined • Equipment block layout identified • Preliminary soil and hydrology report • Environmental permitting requirements and strategy • Content providers	• Plot plans and arrangements made • Soil data • Environmental requirements fixed • Health and safety requirements fixed
Team dynamics		Design status	
• Clear authorization • Multifunctional • Effective decision-making processes • Clear team goals and expectations		• Basic process data Engineering tasks • Written scopes • Major equipment list • Utility, infrastructure and off-site requirements • Analysis of existing equipment • Full factored cost estimate	Engineering tasks • Detailed scopes • Heat and mass balances • Piping and instrument diagrams • Electric single-line diagrams
		Project execution plan	
		Execution strategies (not plans) • Design • Procurement • Construction • Contracting Integrated schedule • Engineering • Procurement • Construction	• Cost/Schedule controls • Contracting strategy • Project organisation • Team participants and roles • Interface and communication plan Plans • Commissioning • Operation • Manpower • Quality assurance

[1] Capex = Capital expenditure
[2] Opex = Operational expenditure

Table E-5 - Phases and durations - Phases and deliverables for construction projects in the manufacturing industry (Merrow, 2011)

F

Current Situation - Process Synthesis

Process synthesis - Legend	
	Milestones
	Deliverables
	Decision-making points
	Problems
Problems	
	Time
	Cost
	Quality
	Organisation
	Information
	Changeability
	Integration

Table F-1 - Current situation - Process synthesis - Legend

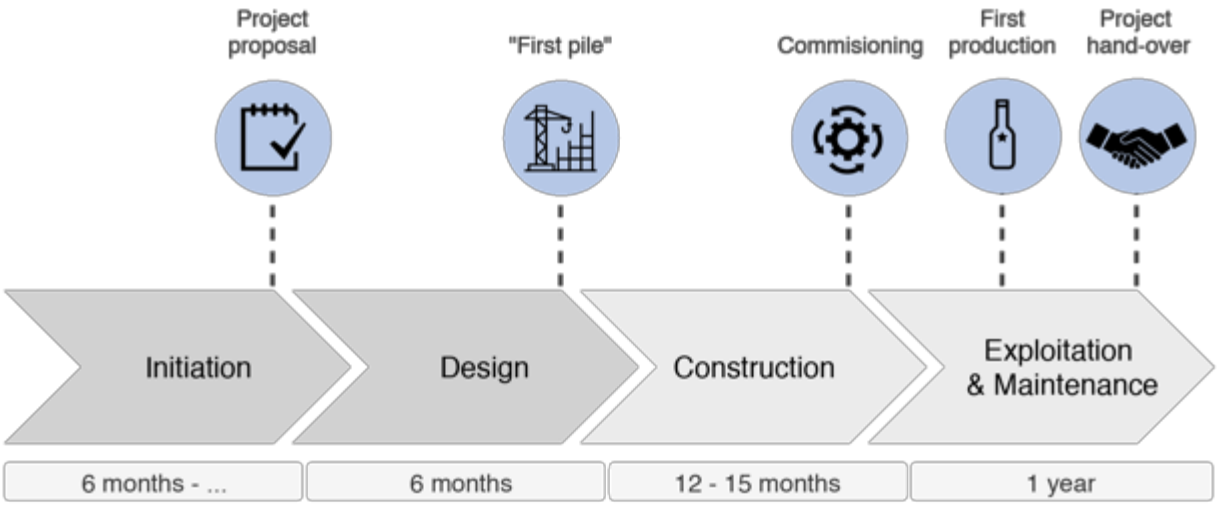

Figure F-1 - Current situation - Process synthesis - Total (Own figure)

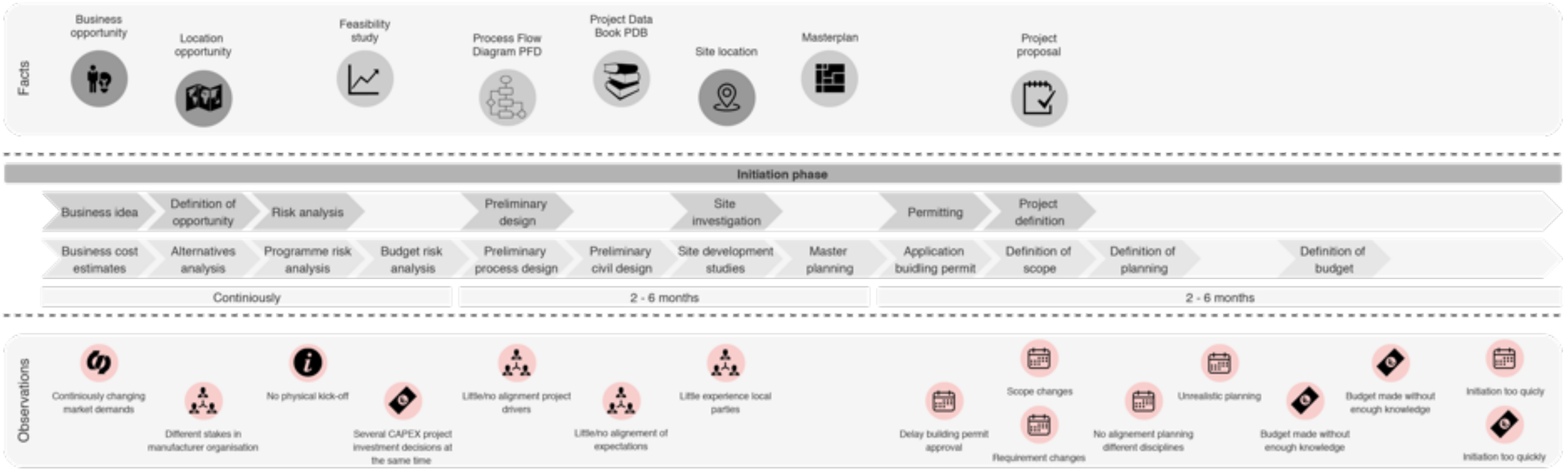

Figure F-2 - Current situation - Process synthesis - Initiation phase (Own figure)

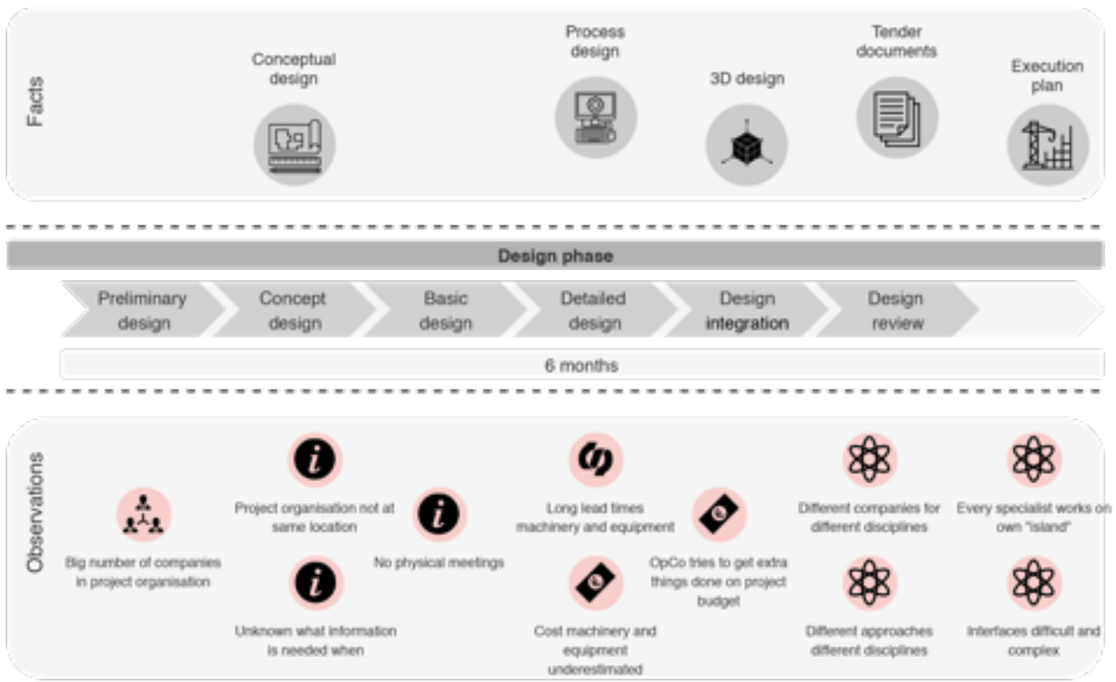

Figure F-3 - Current situation - Process synthesis - Design phase (Own figure)

G

Transition - Literature Review

G.1. Trends

Trends i.e. change drivers				
Political	Economic	Socio-cultural	Technological	Environmental
How the government intervenes in the economy	Include economic growth, interest rates, exchange rates, inflation rate, etc.	Include the cultural aspects and health consciousness, population growth rate, age distribution, career attitudes, etc.	Include technological aspects like R&D activity, automation, technology incentives and the rate of technological change, etc.	Include ecological and environmental aspects such as weather, climate, and climate change
P1 - New legislation and regulation related to waste, carbon footprint, use of water and air discharges (United Nations - Department of Economic and Social Affairs, 2016)	E1 - Growing tension between global opportunity and local interest (The World Bank, 2017b)	S1 - Growing population (United Nations - Department of Economic and Social Affairs, 2017)	T1 - Advanced technology with no borders (The World Bank, 2016b)	EN1 - De-forestation (The World Bank, 2016a)
	E2 - Widening inequality - continued disparity between richest and poorest (The World Bank, 2017a)	S2 - Aging populations (United Nations - Department of Economic and Social Affairs, 2017)	T2 - Internet driven connectivity at every level in society - even in poorest communities (The World Bank, 2016b)	EN2 - Climate change (The World Bank, 2015)
	E3 - Growing affluence driven by expanding middleclass (The World Bank, 2017a)	S3 - Continued urbanisation of society and depopulation of rural areas (The World Bank, 2017b; United Nations, 2015)	T3 - Real time news - on everything and everywhere (The World Bank, 2016b)	EN3 - Growing scarcity of fresh water (United Nations Educational Scientific and Cultural Organization, 2012)
	E4 - Growth of the circular economy (United Nations - Sustainable Development, 2017)	S4 - Migrating influence (United Nations - Department of Economic and Social Affairs, 2017)	T4 - Growth of social networks (like Facebook, Twitter, etc.) (The World Bank, 2016b)	EN4 - Rising awareness of climate change and link to energy solutions (United Nations - Department of Economic and Social Affairs, 2016)
	E-5 - Immediate fulfilment of demands (The World Bank, 2016b)	S5 - Growing shortages of skilled workers (mostly engineers / data scientist) (United Nations, 2017)		EN5 - Rising awareness of inter-connectivity of communities on issues like pollution (United Nations - Department of Economic and Social Affairs, 2016)
	E6 - “Servitisation” of demands - for which the service sector generates more wealth than the manufacturing sector of the economy (United Nations, 2017)	S6 - Growing labour- and skills-mobility as labour market becomes more efficient (United Nations, 2017)		
		S7 - “Healthification” of demands (United Nations - Department of Economic and Social Affairs, 2017)		

Table G-1 - Trends - Changes drivers (The World Bank & United Nations)

G.2. Challenges as Result of Trends

Trends i.e. change drivers	Changing consumer demands				Changing manufacturing demands		
PESTE analysis	Specification	Volume	Moment	Location	Characteristics	Components	Spatial requirements
P1	•				•		
E1				•			•
E3		•					•
E4	•				•		
E5			•			•	•
E6	•				•	•	•
S1		•					•
S2		•					•
S3				•		•	•
S7	•				•		
T2	•		•	•	•	•	•
T3			•				
T4	•		•	•	•		
EN4	•				•		

Table G-2 - Challenges as result of trends - Changing consumer demands and changing manufacturing demands

G.3. Opportunities Industry 4.0

Industry 4.0 technologies clustered from management literature							
McKinsey	BCG						PwC
(Freige, Hammer, Ulrich, Lacovelli, & Bromberger, 2016)	(Scalabre, 2018)	(Küper, Kuhlmann, Köcher, Dauner, & Burggräf, 2013)					(Hook, Geissbauer, Vesdo, & Schrauf, 2016)
Trends	Technologies	Technologies	*Description technologies*	Dimensions	Components	*Description*	Technologies
Increasing data acquisition, computational power and connectivity	Big data	The Industrial Internet of Things	*Interacting field devices with centralized controllers leading to decentralisation of decision making and real-time responses*	Plant Digitisation	Collecting big data Implementing Decentralized Production Steering	*Advanced technology to enable communication among work pieces, machines and people*	Collecting big data
	Internet of things						IoT platforms
							Smart sensors
							Location detection technologies
	Cloud technology	The Cloud	*Data sharing across sites and company boundaries*				Mobile devices
							Cloud computing
		Cybersecurity	*Increased connectivity leads to essential sophisticated identity and access*				Authentication & fraud detection
Increasing data analytics and intelligence	Digitisation and automation of knowledge work	Big Data and Analytics	*Optimising production, quality, saving energy, etc.*		Using big data analytics		Big data analytics and advanced algorithms
	Advanced analytics						
	Artificial intelligence						
Increasing advanced conversion to the physical world	Additive manufacturing (i.e. 3D printing)	Additive Manufacturing	*3D-printing, etc.*		Additive Manufacturing	*3D printing of tools and components*	3D printing
	Advanced robotics (e.g. human-robot collaboration)	Autonomous Robots	*Interact with one another and work safely side by side with humans and learn from them*		Smart Robots	*Self-learning robots performing complex tasks*	
					Collaborative Robots	*Human-robot collaboration and inter-robots collaboration*	
Increasing advanced human-machine interaction	Touch interfaces and next-level GUIs						Advanced human-machine interfaces
	Augmented reality	Augmented Reality	*Real-time information to improve decision making and work procedures*		Augmented Reality	*E.g. through smart glasses helpful in assembly, maintenance and logistics*	Augmented reality/wearables
							Multilevel customer interaction and customer profiling
		Simulation	*Plant operations with real-time data on machines, products and humans*		Production Simulations	*Real-time, 3D representations of production and optimize processes and material flows*	
		System Integration	*Enterprise to shop floor and product to plant to automation*		Immersive Training	*3D simulations to learn realistically*	
				Plant Structure	Multidirectional Layout	*Products autonomously transported through production by communicating with machinery*	
					Modular Setup	*Easy interchangeable and reconfigurable line modules and production machinery*	
					Sustainable Production	*Efficient use of energy and materials*	
				Plant processes	Customer Centricity	*Applying big data analytics to gain insights into how customers use products*	
					Continuous Improvement	*Production process improvements*	

Table G-3 - Opportunities Industry 4.0 - Industry 4.0 technologies clustered from management literature (Freige et al., 2016; Hook et al., 2016; Küper et al., 2013; Scalabre, 2018)

Cyber-physical manufacturing					
(Baena et al., 2017)		(Drath & Horch, 2014)		(Landherr et al., 2016)	
Steps from data to information	Infrastructures	Levels	Contains	Domains	Layers
1. Sources of data	Machines, operators, processes, products, raw material warehouse, finished product warehouse	Physical objects	Sensors	Physical domain	Socio-technical value-adding
					Component layer
2. Technologies to acquire data	Sensors, RFID [1], artificial vision, augmented reality	Cloud	Process data	Cyber domain	Platform layer
3. Data transfer	Internet, fixed networks, wireless communication, protocols				
4. Consolidation of data	Data bases, cloud		Documents		
5. Data-to-information conversion	Smart analytics, multidimensional data correlation, performance prediction	Services	Algorithms		
6. Information management	ERP [2], MES [3], PLM [4], CRM [5]				Application layer
7. Visualisation of the information	Mobile applications, screens, touchscreens, smart boards				

[1] *RFID = Radio frequency identification*
[2] *ERP = Enterprise resource planning*
[3] *MES = Manufacturing execution systems*
[4] *PLM = Product lifecycle management*
[5] *CRM = Customer relationship management*

Table G-4 - Opportunities Industry 4.0 - Cyber-physical manufacturing (Baena et al., 2017; Drath & Horch, 2014; Landherr et al., 2016)

Goals	Current state		Future systems for multi-model data acquisition	
	Scientific knowledge	Problems		
Transparency in production system	Motion data in production: real-time tracking of products and components in production systems and connection to ERP	Manually collected data	Sensor based tracking	Routes and position of people
Real-time production control	Centralised analysis and control production process	Decentralised data	Routes and position of large and highly mobile production devices (e.g. fork lifters)	
	Factory and production system planning: continuous production system planning is predominant	Little standardisation in production systems and data acquisition	Machine vision	Detect and identify types of products
	Simulation-based production optimisation: support strategic planning and operating planning		Detect and identify small production devices and specific products	

Table G-5 - Opportunities Industry 4.0 - Cyber-physical manufacturing - Goals, current state and systems for multi-model data acquisition (Uhlemann et al., 2017)

Smart manufacturing			
Intelligent, IoT-enabled and cloud manufacturing			
Concepts	Description	Characteristics	Supporting technologies
Intelligent manufacturing	Optimising production and product transaction by making full use of advanced information and manufacturing technologies	AI-based smart decision making	Big data processing
		Adaptive and flexible manufacturing systems	Advanced robotics
			Connectivity services
			Sensoring
IoT-enabled manufacturing	On-demand and efficient sharing of resources through application of IoT	Real-time data collection	IoT
	Connections: human-to-human, -to-machine, machine-to-machine	Real-time process information	Wireless production
		Real-time decision making	Big data analytics
			Cloud computing
Cloud manufacturing	Advanced manufacturing model which transforms manufacturing resources into services that can be shared	Manufacturing service distribution and sharing	Cloud computing
		Intelligent capability management	Virtualisation
		Manufacturing cloud service management	IoT

Table G-6 - Opportunities Industry 4.0 - Smart manufacturing - Intelligent, IoT-enabled and cloud manufacturing (Zhong et al., 2017)

G.4. Challenges as Result of Opportunities of Industry 4.0

McKinsey & Company (Breunig et al., 2016)	BCG (Rüßmann et al., 2015)	PwC (Hook et al., 2016)
1. Manufacturers should focus on limited number of Industry 4.0 applications	1. Identify key areas for improvement and relate focus on technological advancements as drivers, i.e. enablers	1. Map out Industry 4.0 strategy
2. Use technology work-arounds to begin implementing, before making large-scale investments	2. Build technological foundation	2. Create initial pilot projects
	3. Analyse long-term impact on workforce and conduct strategic workforce planning	3. Define the capabilities you need
	4. Adapt schooling and training programs and strengthen entrepreneurial and innovation approaches	4. Become an expert in data analytics
3. Build a network of third-party technology providers (single-provider model to a network of integrated technology providers)	5. Develop essential partnerships in digital world	5. Transform into a digital company
		6. Actively plan an ecosystem approach
4. Intra-company cross-functional teams	6. Build right organisational structure and capabilities	
5. Experiment with new business models	7. Define new business models	

Table G-7 - Transition roadmap - Comparison of transition roadmaps within the context of Industry 4.0 from management literature (Breunig et al., 2016; Hook et al., 2016; Rüßmann et al., 2015)

Data Analysis

Appendix H	*Future Situation*	*Process Synthesis*
Appendix I	*Validation*	*Focus Group*
Appendix J	*Validation*	*Questionnaire*

(Picture Royal HaskoningDHV, case study project 3 in Nigeria)

H

Future Situation - Process Synthesis

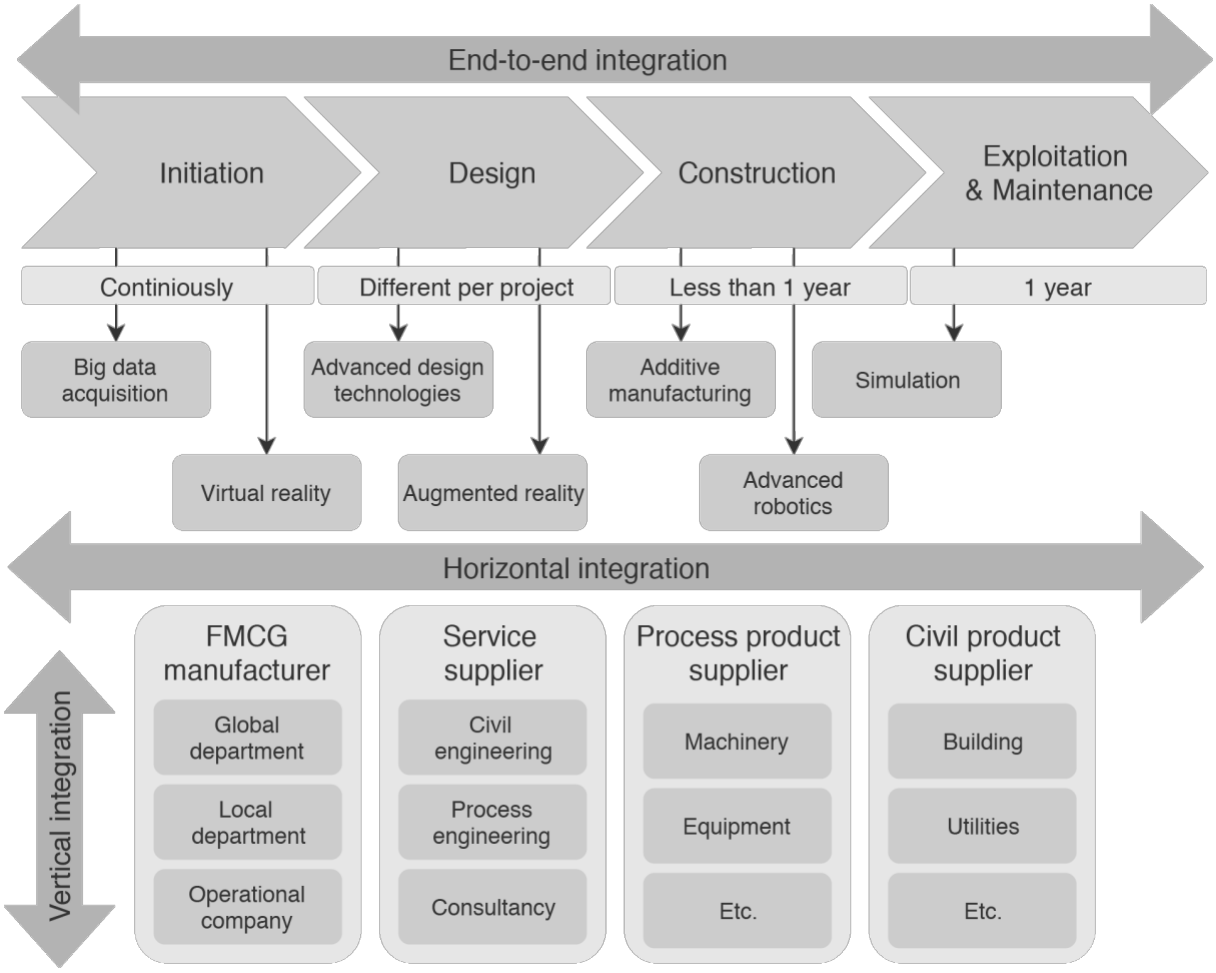

Figure H-1 - Future situation - Process synthesis (Own figure, based on Oesterreich & Teuteberg, 2016)

Validation - Focus Group

I.1. Design

Perspective	Company	Function / Role	Experience
Service supplier	RHDHV	Project Manager and Domain Expert Chains & Logistics	+/- 35 years
Service supplier	RHDHV	Consultant FMCG	+/- 35 years
Service supplier	RHDHV	Consultant Industry & Buildings	1,5 year
Service supplier	RHDHV	Consultant Food and Beverage	1,5 year

Table I-1 - Validation focus group - Design - Attendees

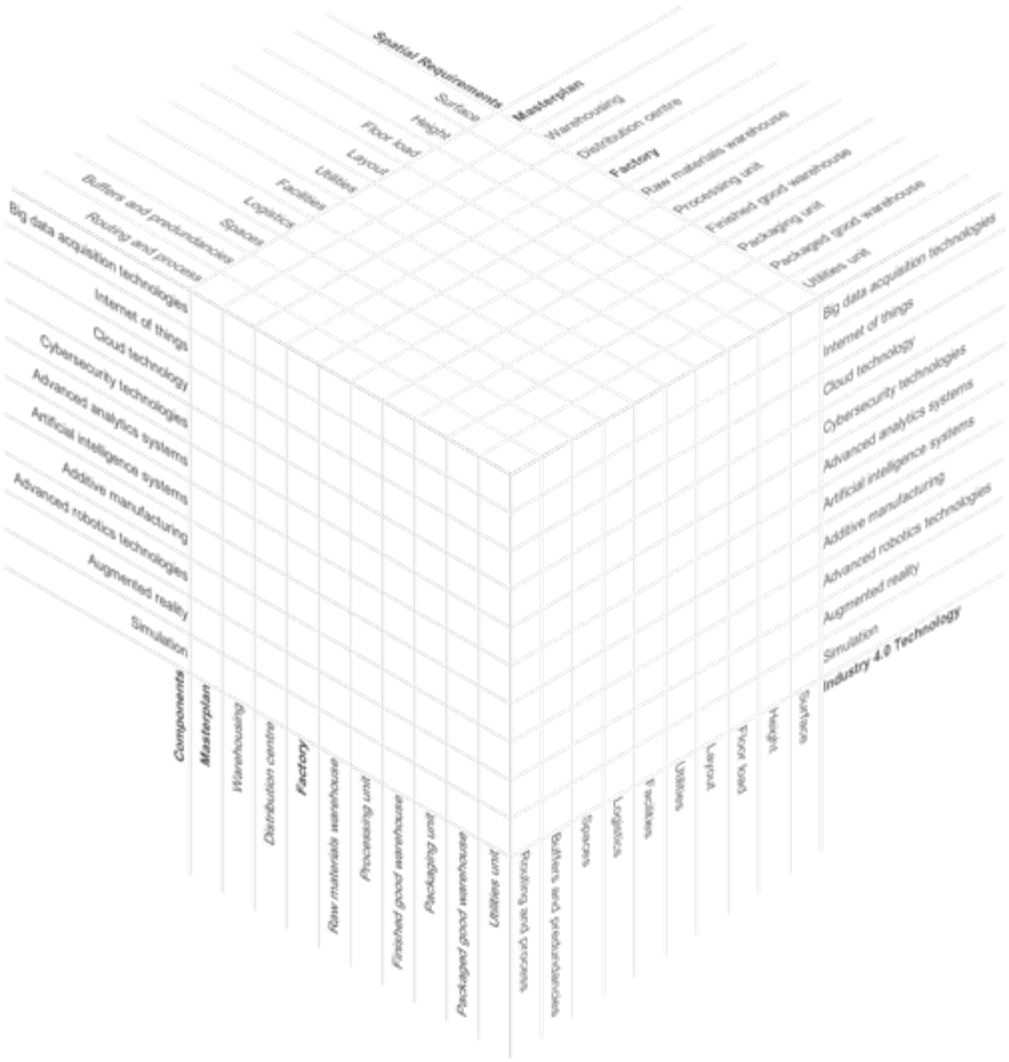

Figure I-1 - Validation focus group - Design - Matrix (Own figure)

I.2. Result

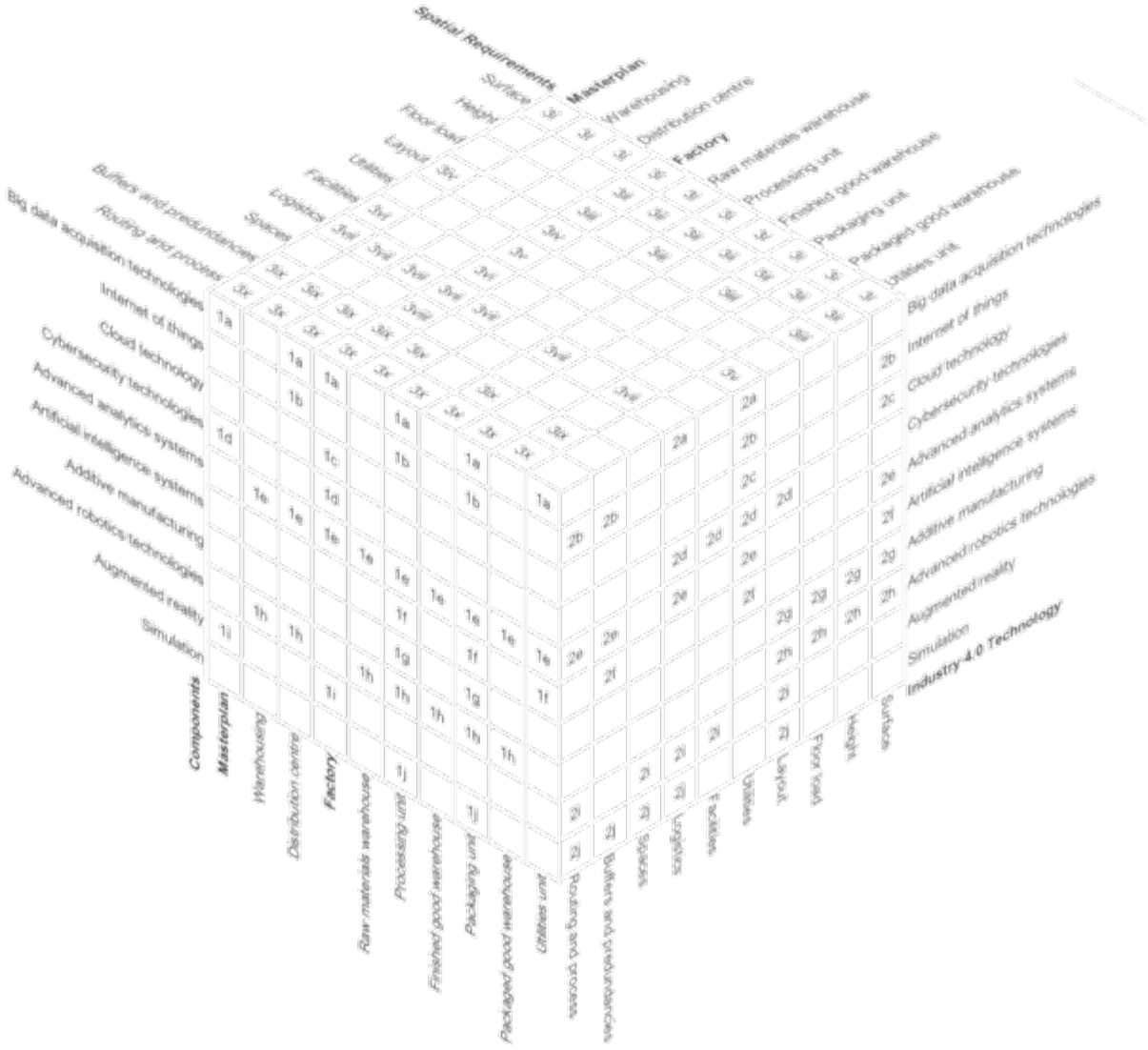

Figure I-2 - Validation focus group - Result - Matrix filled-in (Own figure)

1 - Industry 4.0 technologies influencing FMCG factory components	
1a	Big data acquisitioning technologies will influence different components by collecting data within these components.
1b	The internet of things will mainly influence the distribution centre, processing unit and packaging unit by integrating the processes in these components.
1c	Cloud technology will influence the factory and all its sub components, by storing all the data primary and secondary processes of the factory.
1d	Cyber security technologies will influence the main components, the master plan and the factory, by for example, advanced identification technologies.
1e	Advanced analytics systems will steer processes in all components that directly facilitate processes in some kind of way.
1f	Artificial intelligence systems will influence the components that facilitate rather complex processes.
1g	Additive manufacturing will influence the processing and packaging unit, because in these components this technology will be used.
1h	Advanced robotics will influence all components with some kind of equipment, which can be replaced with advanced robotics technologies.

1i	Augmented reality will mainly influence the masterplan and the factory, because these are the main components in which the positioning of the other sub components is established. The design of the positioning can be done with the use of augmented reality.
1j	Simulation can be used to simulate and optimise processes and will therefore mainly influence the processes in the processing unit and packaging unit.
2 - Industry 4.0 technologies influencing FMCG factory spatial requirements	
2a	Big data acquisition technologies will influence the logistical and utility spatial requirements, because the acquisition of big data needs an infrastructure and therefore certain utilities, such as electricity supply, IT networks, etc. are needed.
2b	The internet of things will lower the spatial surface required, will put extra pressure on the utilities (same as in 2a), will lower the spatial buffer and redundancy requirements and will lower the spatial routing and process requirements. The internet will lower certain spatial requirements because it enables the optimisation of processes.
2c	The spatial surface requirement will be lower, by lowering the physical storage of data, and the pressure on certain utilities will be higher, by increasing need of e.g. electricity, internet, etc., due to cloud technology.
2d	The layout, the utility, the facility and the logistical spatial requirements will be influenced by cybersecurity technologies, because of the decreasing need for physical security.
2e	Advanced analytics systems will enable the optimisation of the processes and therefore the spatial requirements for surface, buffers and redundancies will be lower. Moreover, the logistics, routing and process will be optimised and the pressure on certain utilities will be higher.
2f	Artificial intelligence systems will also be used for the optimisation of processes.
2g	Additive manufacturing will influence the surface, heights, floor loads and the layout of factories by replacing other production systems.
2h	Advanced robotics technologies will influence factories in the same way as additive manufacturing technologies.
2i	The spatial requirements for the layout, facilities, logistics and spaces are all determined in the design phase of the factory. The use of augmented reality in the design phase will probably influence these spatial requirements.
2j	Simulation can be used to simulate and optimise processes and will therefore mainly influence the layout, logistical, spaces, buffers and redundancies and routing and process spatial requirements.

Table I-2 - Validation focus group - Result

J

Validation - Questionnaire

Personal information	
Experience in the field of (multiple answers possible)	Construction
	Fast Moving Consumer Goods
	Manufacturing
Years of professional experience (in the field(s) named above)	
Perspective	
Project drivers	
0.1 - What do you consider to be the most common project driver(s) for construction projects in the in the manufacturing industry? (multiple answers possible)	Time
	Cost
	Quality
	Scope
	Changeability
	Integration
0.2 - What do you consider to be the most common project driver(s) for construction projects in the FMCG manufacturing industry? (multiple answers possible)	Time
	Cost
	Quality
	Scope
	Changeability
	Integration
Optional explanation answers questions 0.1 & 0.2 (open question)	
0.3 - Do you consider other project drivers to be relevant in the FMCG manufacturing industry? (open question)	
Current output	
1.1 - Which of the following classifications of FMCG factories do you consider to be the most related to the spatial requirements of FMCG factories?	Product type
	Product substance
	Type of manufacturing process
Optional explanation answer question 1.1 (open question)	
1.2 - What do you consider as main problems of the output of construction projects in the FMCG manufacturing industry: the FMCG factories? (open question)	
1.3 - Do you think limited production changeability of FMCG factories is a problem? (yes/no)	
1.4 - Do you think limited integration of disciplines in FMCG factories is a problem? (yes/no)	
Optional explanation answer question 1.3 & 1.4 (open question)	
Current process	
2.1 - What do you consider to be the most common causes for time overruns in construction projects in the FMCG manufacturing industry? (open question)	
2.2 - What do you consider to be the most common causes for organisational problems in construction projects in the FMCG manufacturing industry? (open question)	
2.3 - What do you consider to be the most common causes for problems related to information management in construction projects in the FMCG manufacturing industry? (open question)	
2.4 - Do you consider other problems to be relevant related to the FMCG manufacturing industry? (open question)	
Transition - Industry 4.0	

3.1 - What do you consider to be the most relevant technologies to implement in the manufacturing industry? (multiple answers possible)	Collecting big data
	IoT platforms
	Smart sensors
	Location detection technologies
	Mobile devices
	Cloud computing
	Authentication & fraud detection
	Big data analytics and advanced algorithms
	3D printing
	Advanced human-machine interfaces
	Augmented reality/wearables
	Multilevel customer interaction and customer profiling
3.2 - What do you consider to be the most relevant technologies to implement in the FMCG manufacturing industry? (multiple answers possible)	Collecting big data
	IoT platforms
	Smart sensors
	Location detection technologies
	Mobile devices
	Cloud computing
	Authentication & fraud detection
	Big data analytics and advanced algorithms
	3D printing
	Advanced human-machine interfaces
	Augmented reality/wearables
	Multilevel customer interaction and customer profiling
3.3 - What do you consider to be the most relevant technologies to implement in the construction industry? (multiple answers possible)	Collecting big data
	IoT platforms
	Smart sensors
	Location detection technologies
	Mobile devices
	Cloud computing
	Authentication & fraud detection
	Big data analytics and advanced algorithms
	3D printing
	Advanced human -machine interfaces
	Augmented reality/wearables
	Multilevel customer interaction and customer profiling
3.4 - Did you choose different technologies for the manufacturing industry and the FMCG manufacturing industry? (yes/no)	
3.5 - Did you choose different technologies for the manufacturing industry and the construction industry? (yes/no)	
Optional explanation answers question 3.1, 3.2, 3.3, 3.4 & 3.5 (open question)	
3.6 - Do you consider other technologies to be relevant for the FMCG manufacturing industry? (open question)	
Future FMCG factory	
4.1 - Do you consider cyber-physical systems to be relevant for the FMCG manufacturing industry? (yes/no)	
Optional explanation answer question 4.1 (open question)	

4.2 - Which concept do you do you consider to be most relevant for the FMCG manufacturing industry? (multiple answers possible)	Intelligent manufacturing
	IoT-enabled manufacturing
	Cloud manufacturing
4.3 - Do you consider other systems and/or concepts to be relevant for the FMCG manufacturing industry?	
Future process	
5.1 - Which type(s) of integration do consider to be most relevant for the manufacturing industry? (multiple answers possible)	Horizontal
	Vertical
	End-to-end
	All even
5.2 - Which type of integration do consider to be most relevant for the FMCG manufacturing industry? (multiple answers possible)	Horizontal
	Vertical
	End-to-end
	All even
5.3 - Which type of integration do consider to be most relevant for the construction industry? (multiple answers possible)	Horizontal
	Vertical
	End-to-end
	All even
Optional explanation answers question 5.1, 5.2 & 5.3 (open question)	
Transition roadmap from current to future situation	
6.1 - What do you consider to be the most beneficial of implementing the technologies (chosen in question 3.1) in the manufacturing industry? (multiple answers possible)	Time, cost savings, on-time, on-budget
	Improving quality
	Improving collaboration
	Improving, documentation and communication
6.2 - What do you consider to be the most beneficial of implementing the technologies (chosen in question 3.2) in the FMCG manufacturing industry? (multiple answers possible)	Time, cost savings, on-time, on-budget
	Improving quality
	Improving collaboration
	Improving, documentation and communication
Optional explanation answers question 6.1, 6.2 & 6.3 (open question)	
6.4 - What do you consider to be the most common challenges implementing the technologies (chosen in question 3.1) in the manufacturing industry? (multiple answers possible)?	Time, cost savings, on-time, on-budget
	Improving quality
	Improving collaboration
	Improving documentation and communication
6.4 - What do you consider to be the most common challenges implementing the technologies (chosen in question 3.1) in the manufacturing industry? (multiple answers possible)	High implementation cost
	Organisational and process changes
	Knowledge management and enhancement of existing communication networks
	Lack of standards
6.5 - What do you consider to be the most common challenges implementing the technologies (chosen in question 3.2) in the FMCG manufacturing industry? (multiple answers possible)	High implementation cost
	Organisational and process changes
	Knowledge management and …
	Lack of standards
6.6 - What do you consider to be the most common challenges implementing the technologies (chosen in question 3.3) in the construction industry? (multiple answers possible)	High implementation cost
	Organisational and process changes
	Knowledge management and …
	Lack of standards
Optional explanation answers question 6.4, 6.5 & 6.6 (open question)	

Table J-1 - Validation questionnaire - Design

		Respondent 1		Respondent 2		Respondent 3		Respondent 4		Respondent 5	
Personal information											
Experience in the field of	Construction	•		•		•		•			
	Fast Moving Consumer Goods	•		•		•		•			
	Manufacturing			•		•		•		•	
Years of professional experience (in the field(s) named above)		8		30		12		30		25	
Perspective		FMCG manufacturer		Service supplier		Service supplier		Service supplier		Process product supplier	
Project drivers											
		General manuf.	FMCG manuf.	General manuf.	FMCG manuf.	General manuf.	FMCG manuf.	General manuf.	FMCG manuf.	General manuf.	FMCG manuf.
0.1 - Common project driver(s) for construction projects in the in the manufacturing industry? 0.2 - Common project driver(s) for construction projects in the FMCG manufacturing industry?	Time	•	•	•	•	•	•	•	•	•	•
	Cost	•	•	•	•	•	•	•	•	•	•
	Quality	•	•			•		•	•		
	Scope	•	•								
	Changeability							•	•		•
	Integration							•	•		
Optional explanation answers questions 0.1 & 0.2		n/a		Time to be seen as “time to market”.		In the FMCG industry “time to market” is often critical. The products by various competitors may have similar attributes, hence moving in first is often a very important factor.		Lean design in such that all flows are optimised, and no constraints introduced by the nature of the design. Dependant on region for construction, then safety in design and construction phases is also a driver.		General manufacturing driver: extensions possible.	
0.3 - Other project drivers relevant for the FMCG manufacturing industry?		Safety - any incidents can destroy the reputation of the company.		Operational costs and nowadays also “green” manufacturing.		n/a		Adaptability. i.e. able to repurpose the factory in a modular design sense.		n/a	
Current output											
1.1 - Which of the following classifications of FMCG factories most related to the spatial requirements of FMCG factories?	Product type	•								•	
	Product substance										
	Type of manufacturing process			•		•					
Optional explanation answer question 1.1		n/a		Type of manufacturing process has direct impact on handling and logistics.		n/a		They all have bespoke spatial requirements, so it is difficult to differentiate. In a highly automated factory, then space is limited and access and entrees for people can increase the spatial need. In a process that has a high safety risk, then more space is required due to codes of practice and regulations ensuring minimal clearances for example.		n/a	
1.2 - Main problems of the output of construction projects in the FMCG manufacturing industry: the FMCG factories?		Projects are slow and not flexible for changes.		Long realisation (construction) time compared to market developments.		Main problems are delays and cost overruns, in addition the factory/process may be already obsolete by the time the facility is commissioned.		n/a		Qualification and selection of subcontractors.	
1.3 - Do you think limited production changeability of FMCG factories is a problem?		Yes		Yes		Yes		Yes		Yes	
1.4 - Do you think limited integration of disciplines in FMCG factories is a problem?		n/a		No		Yes		Yes		No	
Optional explanation answer question 1.3 & 1.4		n/a		n/a		n/a		The historic design of FMCG factories limits the ability to adapt and repurpose them. Only if you are designing a brown- or green field you have the opportunity to design in changeability.			

Current process					
2.1 - Most common causes for time overruns in construction projects in the FMCG manufacturing industry?	Changes.	Under-estimation of time required to come to a final design with all parties involved (stakeholders)	Unforeseen local circumstances (site specifics, local procedures, etc.), changes and consequent rework, time lost in transferring data/information from one party to the next (e.g. from the designer to contractor).	Poor project management.	Changes in requirements and design.
2.2 - Most common causes for organisational problems in construction projects in the FMCG manufacturing industry?	Project management team disconnected from the future operational team.	No clear responsibilities, communication lines and authorities (decision making) internal as well as external (client).	Communication issues and information mismanagement.	Lack of resources meaning some roles are covered by a single person.	Missing definitions and standards.
2.3 - Most common causes for problems related to information management in construction projects in the FMCG manufacturing industry?	Construction projects are not the core business of the FMCG industry, so misunderstandings (even on simple topics) are common. Communication is then fundamental.	No clear procedures on information management: pending-available / conceptual-final / approvals.	The amount of data/information is becoming vast, the projects are often too complex.	Inadequate control of project documentation and complicated information flows.	Interpretation of reports, true content and not visiting sites.
2.4 - Other problems relevant related to the FMCG manufacturing industry?	n/a	Early involvement of local expertise.	Lack/insufficiency of competent technical resources in the organisation.	Clients are sometimes seeking ambitious timescales or perceived small changes in scope lead to major design or project implementation impact.	Decision-making processes

Transition - Industry 4.0																
		General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.
3.1 - Most relevant technologies to implement in the manufacturing industry? 3.2 - Most relevant technologies to implement in the FMCG manufacturing industry? 3.3 - Most relevant technologies to implement in the construction industry?	Collecting big data	•	•						•	•						
	IoT platforms						•	•	•	•	•	•		•	•	•
	Smart sensors	•	•	•	•	•		•	•		•	•	•		•	
	Location detection technologies									•	•	•	•			
	Mobile devices			•						•	•	•	•			•
	Cloud computing						•	•	•	•			•	•		•
	Authentication & fraud detection											•				
	Big data analytics and advanced algorithms	•	•					•	•	•	•	•		•	•	•
	3D printing	•							•	•				•		•
	Advanced human-machine interfaces				•	•		•	•	•	•	•	•			
	Augmented reality/wearables						•	•		•	•	•	•			•
	Multilevel consumer interaction and profiling	•	•					•	•							
3.4 - Did you choose different technologies for the manufacturing industry and the FMCG manufacturing industry?		No			No			Yes			Yes			Yes		
3.5 - Did you choose different technologies for the manufacturing industry and the construction industry?		Yes			Yes			Yes			Yes			Yes		
Optional explanation answers question 3.1, 3.2, 3.3, 3.4 & 3.5		n/a			n/a			The potential e.g. for 3D printing may be higher in manufacturing (e.g. in the automotive, aerospace sectors) as compared to the FMCG industry. 5D BIM is a very important technology for the construction industry.			n/a			General manufacturing: solutions easy to understand and fast accepted by operators, to make users happy		
3.6 - Other technologies relevant for the FMCG manufacturing industry?		n/a			n/a			Artificial intelligence is an important technology, in particular in the supply chain management.			Digital simulations			Solution for easy logistics and delivery on demand		

Future output																
4.1 - Cyber-physical systems relevant for the FMCG manufacturing industry?		Yes			Yes			Yes			Yes			Yes		
Optional explanation answer question 4.1		n/a			Sensoring and human-machine interface			n/a			n/a			n/a		
4.2 - Which concept most relevant for the FMCG manufacturing industry?	Intelligent manufacturing				•			•			•					
	IoT-enabled manufacturing							•						•		
	Cloud manufacturing							•								
4.3 - Other systems and/or concepts relevant for the FMCG manufacturing industry?		n/a			n/a			n/a			Lean Supply Chain 4.0					
Future process																
		General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.
5.1 - Which type(s) of integration most relevant for the manufacturing industry? 5.2 - Which type of integration most relevant for the FMCG manufacturing industry? 5.3 - Which type of integration most relevant for the construction industry?	Horizontal				•	•		•	•							
	Vertical							•	•				•			
	End-to-end	•	•	•			•	•	•	•	•	•		•	•	•
	All even															
Transition roadmap from current to future situation																
		General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construct.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.	General manuf.	FMCG manuf.	Construc.
6.1 - Most beneficial of implementing the technologies (chosen in question 3.1) in the manufacturing industry? 6.2 - … (chosen in question 3.2) in the FMCG manufacturing industry? 6.3 - … (chosen in question 3.3) in the construction industry?	Time, cost savings, on-time and on-budget	•	•	•			•	•	•	•	•	•	•	•	•	•
	Improving quality	•	•	•	•	•	•	•	•	•	•	•				
	Improving collaboration							•	•	•		•	•	•		•
	Improving documentation and communication	•	•	•						•	•	•	•		•	•
6.4 - Most common challenges implementing the technologies (chosen in question 3.1) in the manufacturing industry? 6.5 - … (chosen in question 3.2) in the FMCG manufacturing industry? 6.6 - … (chosen in question 3.3) in the construction industry?	High implementation cost	•	•	•				•	•	•	•	•	•			•
	Organisational and process changes	•	•	•	•	•		•	•	•	•	•	•	•	•	•
	Knowledge management and enhancement of existing communication networks	•	•	•			•	•	•	•	•	•	•	•	•	•
	Lack of standards										•	•	•			
Optional explanation answers question 6.4, 6.5 & 6.6		n/a			Manufacturing industry: Change management; Construction industry: Integration of knowledge and information.			Standards are likely to be developed as new technologies get implemented, lack of standards is not a big challenge in my perception.			n/a			n/a		

Table J-2 - Validation questionnaire - Result