Interactive Session for creating awareness of sharing concepts in construction logistics

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Preface

Dear reader,

This Master's thesis was performed as a conclusion of the Masters of Science program in Management of Technology at TU Delft. For the past six months, I have been working on my thesis project and have developed immense learnings towards the construction sector and logistics processes in the chain.

This project was conducted at Rotterdam University of Applied Sciences under the initiative of TKI Dinalog. The work package of the construction logistics sector aimed at providing solutions for sharing concepts for the small and medium-sized enterprises (SMEs) to better prepare the sector for the upcoming Green Deal 2025. I was chosen for the project by Alexander de Vries and Ron Van Duin to develop a serious game or a simulation to increase awareness of the openness of the sharing concepts in the chain. I started with a literature review regarding the working of the sector and interview analysis to understand the challenges encountered by the SMEs and applicable solutions that could help them with efficient ways of working particularly towards capacity-sharing solutions. This policy poses restrictions to the entry of vans, the most widely used transport in the construction sector, in the inner city areas thereby acting as a major motivator for the project. This balance of business priorities with environmental regulations was quite interesting to explore for the project and educate SMEs towards openness of sharing solutions.

I am quite thankful to my committee members who guided me through every step of my project. I would like to thank my external supervisor, Alexander de Vries for providing insights and basis for the construction sector and providing required help regarding data gathering for the session. Furthermore, I am also grateful to my first supervisor, Marcel Ludema for guiding me through his immense knowledge of the sector to increase the quality of the result of this thesis. Also, an immense thanks to Fernando Kleiman for guiding me with all the necessary help required to conduct the thesis may it be conceptual or psychological especially during these challenging times. I am grateful for the support of my chair, Bert Enserink for the patience and advice regarding the realistic achievement of the project.

I want to thank my parents to provide me all the courage and patience to pursue this course, especially during these challenging times. Most importantly, an immense thanks to my husband and his family who had been by my side throughout this course providing the necessary encouragement and help required for my success including the completion of this project.

Regards
Ayushi

Summary

The increase in urbanisation leads to increasing demand for construction activities in and around the cities. This would include new construction and also maintenance or renovation of old establishments to accommodate more people. The increase in construction practices would involve movement of heavy construction vehicles across congested areas and roads of the cities leading to increased congestion, air pollution, noise pollution and safety hazards for the population. Furthermore, the upcoming Green Deal 2025 would restrct the entry of construction vans in the inner city areas thus leading to a reverse stream of problems for the sector.

The construction industry suffers from a low efficiency problem owing to its fragmented and unique nature of each project. The involvement of multiple stakeholders such as client, main contractor, sub-contractors and the producers of building materials for each activity poses information exchange issues in the chain. The inter-dependencies of activities also pose a threat to the deliverable for the projects. In addition, the construction industry comprises of SMEs that specialise in various building materials and technologies, but their presence adds to the data sharing capabilities in the chain due to their conscious nature. These reasons lead to delayed processes, adhoc deliveries and occasionally less full-truck load capacity deliveries to the project sites. Thus, the sector requires better information exchange amongst the project stakeholders and truck capacity sharing activities to streamline the processes and reduce congestion and emission levels for construction logistics.

The aforementioned problems of the sector were addressed by utilizing innovative concepts such as use of construction consolidation centres (CCC), synchromodal possibilities and effective data sharing in the chain using 4C concepts. But these solutions require high capital costs and pose financial limitations for SMEs in the chain. TKI Dinalog proposes the use of collaborative sharing solutions with shared costs and publicly-organised solutions for SMEs. These solutions preconditions collaboration and other trade-offs that could hinder the competitiveness of the SMEs that rely on their expertise. Also, in order to incentivise the financial implications and qualitative implications of these solutions, a lack of a business case poses limitations to the implementation of the solution.

This project is part of a larger project carried out at the Rotterdam University of Applied Sciences under the initiative of TKI Dinalog. The adjoining research to this project focused on the functions and working of the sector and has been conducted along with interviews with supplier companies, builder contractor companies and logistics companies, platform developers separately. These interviews highlight the needs and challenges posed by respective stakeholder activities and business models. Moreover, given the aforementioned challenges in the construction sector, the SMEs in the sector are aware regarding the existing solutions undertaken by bigger companies but due to data conscious nature of these companies, an openness towards these new ways of working is low that hinder their adoption. Also, due to less data available on the impacts of these solutions, their adaptability in the sector is very low. A facilitated session is required to create awareness for these concepts in the chain by presenting business case of the solutions and possibilities of addressing these solutions collaboratively by sharing costs and benefits.

Hence, the project objective is summarized as follows:

¨To design and evaluate an interactive session that facilitates discussion and creates awareness in order to encourage openness towards sharing possibilities for SMEs in the construction logistics sector¨

In order to attain the project objective stated above, a problem solving approach is utilized to derive the research sub-questions and design objective in the project. A 5WH methodology was followed to delve into the problem and summarize the sub- research questions for the project. The problem was summarised in RQ1 extending to the RQ2 and RQ3 with restricted opportunities whereas the how question was aimed to formulate the design objective as DO and then to RQ5. These sub- questions are summarized below:

RQ1: What are the current challenges/ bottlenecks for SMEs in construction logistics ?

RQ2: What are the session requirements that would be utilized for raising awareness for sharing concepts in the construction logistics chain?

RQ3: Which sharing solutions would be appropriate for the SMEs in the construction chain?

Design Objective(D.O.): How to design and evaluate the interactive session that raises awareness of sharing concepts for SMEs in the construction supply chain?

RQ5: What was the impact of the session on the participants?

Next, a general product design methodology coupled with experiential learning via triadic game design methodology was adopted to design the interactive session. The methodology comprises of a detailed model that includes the problem objective definition, determining the detailed user requirements and then selecting the right elements for the session design from the current defined requirements to effectively achieve the session purpose. The methodology also guides the designer for operationalizing the elements via iterative prototype design. Furthermore, the evaluation of the design to increase the quality and test the impact measurement is conducted followed by the improvements for the final design. Finally, a session manual is facilitated at the end for the participants as well as the facilitator of the session.

Based on the project objective, the project deliverable are set as per the low quality deliverable and high quality deliverable for the project. The low deliverable aims to meet the minimum requirements such as presenting a realistic business case and facilitate discussion among players. The high deliverable is targeted towards the impact of the session and if the participants will implement/ consider these solutions in the upcoming projects.

Also, the project scope was defined based on the inclusion of impacts of the solutions and include mostly the quantitative costs of transport involved and a few impacts such as productivity and flexibility of data- sharing. But the organisational and behavioural changes are currently scoped out of the costs and benefits for the project.

The next section focuses on the literature scope of the problem that highlights the urban logistics scope for the project and deep-dives into the problems and pre-conditions of the sector such as loosely-coupled relationships, multitude of supply flows, construction process and SME dominance and their nature of work in the sector. This section is contributes to the findings of RQ1 and summarizes the problems of SMEs in the construction sector. In order to address the inefficiencies in the sector, efficient logistics solutions need to be targeted for SMEs in the sector that acts as a research gap as well. TKI Dinalog

proposes the use of exploration of shared economy models for the sector. Furthermore, the shared economy concept is explored via literature research study and a shared economy model was identified that needs to be appropriately mapped given the sector situation for SMEs. This would set as a basis for identifying the right kind of solutions for the sector. As per the analysis from the interviews conducted from this project, the capacity- sharing solution was identified as the most appropriate sharing for the sector given the low innovation adoption nature of the sector. Based on the literature research, the conclusion was to devise the solutions focused on the finishing phase of the construction process since the other phases offer low opportunities of capacity-sharing in the sector.

Next, elements to design and engaging session for participants were explored to understand the requirements of the collaborative session. The requirements indicated towards an engaged session with increasing challenge requirements through flow theory, scaffolding mechanism and game-like assessments to provide a suitable learning environment for participants. Moreover, a selection of stakeholder representation in the game was realized via stakeholder analysis. Furthermore, solutions to be represented in the session need to be determined. For this, shared economy practices were explored in various sectors to establish suitable solutions for actors in the chain based on the shared economy practices mapping and Green Deal requirements. Since, there are multitude of supply flows to a construction site, the integrated solutions was decided to be formed. The final solutions to be included in the session were based upon the common solutions determined from the interviews conducted for the adjoining research fo this project. The final integrated solutions are summarized below:

1. White label hub solution: White-label hub + Regional 3PL contact+ e-bikes at hub+ Logistics manager per project+ Waste carried downstream from sites

2. Strict Window timing solution:Transport collects goods from all suppliers at once+ Regional 3PL contact + Carpooling with tools + Logistics manager per region + Waste carried downstream from sites

3. White-labelled truck solution: Coupling/ de-coupling of trailers+ Regional 3PL contact+ Carpooling with tools+ Logistics manager per region+ Waste carried downstream from sites

4. Platform economy solution : White-label hub from DHL or other sectors+ equipment via platform economy Werflink + carpooling with tools+ logistics manager per region + Waste carried downstream from sites

The above solutions were based on capacity-sharing in the final phase of the construction process and were assessed for their costs and benefits calculations in the session. However, in order to encourage the participants for sharing other resources such as combined purchasing like ZARA does or more efficient working of sharing solutions such as kitting services incorporated with the hub solution similar to IKEA´s model are also presented in the session.

Due to the absence of a particular project for cost-benefit calculation analysis, a simple baseline case was utilized in this project for detailed calculations of costs and emissions in the chain. The costs included handling costs, storage costs at supplier and hub and transport costs for material delivery. Next, the interviews and literature study were analysed to devise the particular tensions & trade-offs of the solutions for the actors in the chain that depicted the qualitative effects of flexibility and productivity in the chain for each stakeholder. The tensions and trade-offs represented the qualitative impacts of the solutions such as bearing the costs of organisation, increased productivity, behavioural changes to be incorporated such as better plannability, less source material collection practices and data-sharing in the chain leaning towards lower flexibility for the parties that would be used as an impact parameter in the session.

To incorporate the above impacts in a collaborative discussion for the actors, an experiential learning session is designed using an interactive platform and competitive elements to keep the players engaged. The platform was chosen to be low-tech due to the inexperience of players as gaming experts and was finalized to be Google Sheets since it offers easy sharability in online sessions as well. The other elements such as Flow of the session, collaborative session design and scaffolding mechanism via debriefing were operationalized in this section. Thus, the practical session design inspired by existing examples and suitable for the required play-setting was constructed that served as the basis of design of the session such, break-down of session into mini-sessions replicating the scaffolding mechanism and flow theory.

The session would accommodate 7 players at once and was divided into 3 mini-sessions followed by de-briefing. The first session was treated as a tutorial session wherein the participants had to understand the mechanisms of the platform game play and learn to analyse the feedback provided by the platform. The second mini-session was devised as a actual game play with added challenge of saving emissions as well. Next, a gain-sharing mechanism mimicking the contract-signing is formulated where participants could analyse the impact of cost-sharing and their respective chain optimisation techniques based on their inputs in the platform.

The session was divided into 3 main tasks: operational costs of solutions, devising the ways of session organisation and cost/ gain-sharing mechanisms of organisation costs and chain costs such as reduced transport costs or reduced material costs. An iterative design process was adopted for the session design that was evaluated for its quality & goal attainment.

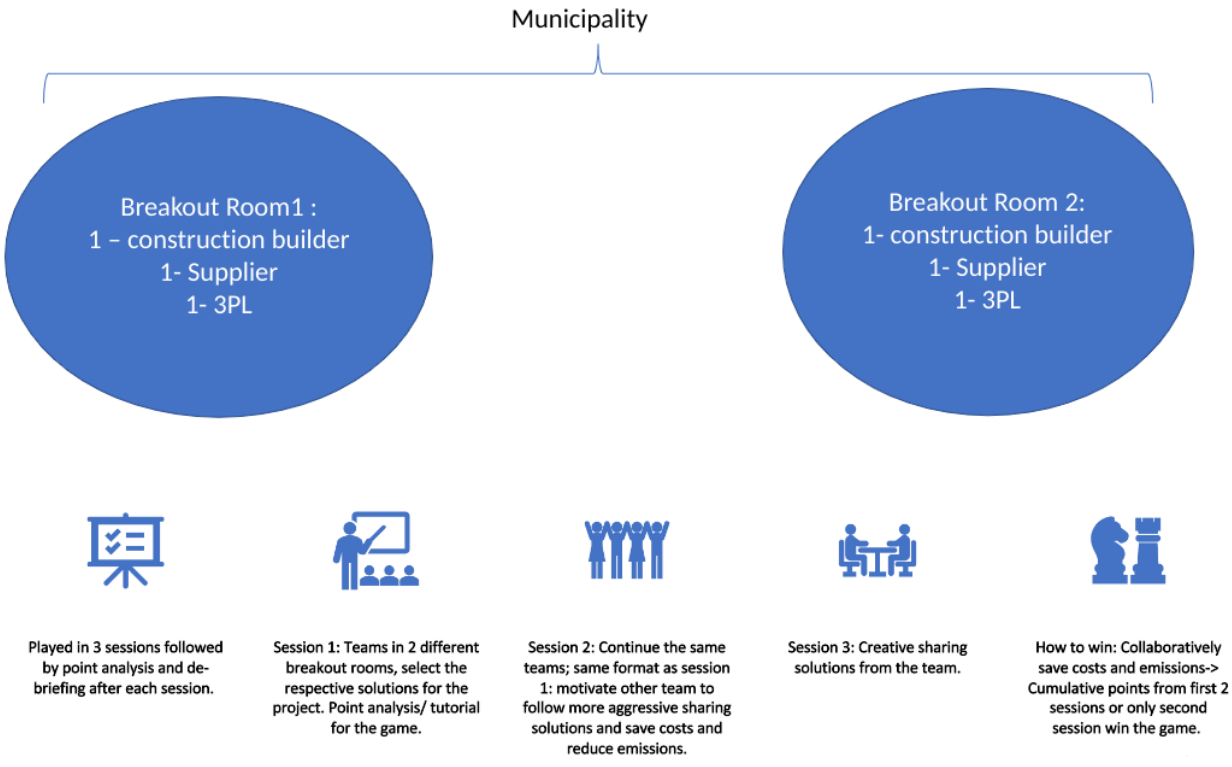

Figure 1: Overall session

The playtest session constituted of industry experts as participants to evaluate the session based on the attainment of requirements set for the project & improve the overall quality and impact for the industry players. The feedback from this evaluation was used to improve the session such that it is more suitable for the industry players & overall goal attainment for this project. The session did fulfill the awareness requirement for the targeted participants & simulating interplay between trade-offs

that these sharing concept would entail. The improvements advised for the devised session suggested improvements towards the quality of facilitation due to high complexity of the platform. Thus, multiple walk-through of the platform was added in the session including a pre-session mail to the participants along with the manual such as to allow the participants to grasp the mechanisms quickly. Also, assumptions and their explanation was requested to be included in the platform as well and needed to be communicated before the session to provide an understanding of limitations of the values and solutions to the participants.
Also, improved version of the session could not be evaluated with the actual industry players given the unavailability of people and is reported as a hard-thinking protocol for the project. The hard-thinking protocol utilizes the thinking aloud protocol devised in literature with the perspective of multiple roles assumed by the researcher itself. An actual session was mimicked and explored as per the solution chosen by each actor based on their previous experiences and attitudes defined beforehand. Navigation of solutions by a single team in detail is represented with preferences and justification from each actorś perspectives. Even the motivation from the competitive spirit triggered by the gaming elements in the session was explored in this session devising the changed behaviour towards more aggressive solutions. The gain-sharing interaction is also represented via the perspective of the stakeholders facilitated in the platform. Furthermore, improvements observed in both evaluations are assessed and are taken up for further research recommendations.

The project concludes that the overall objective of the project of achieving awareness was attained by the session by facilitating collaborative discussion and presenting trade-offs for the parties in the chain. However, the complexity of the session due to realistic representation of multitude of options could lead to overload of information and may need to be simplified and restrict exploration of all the possible solution organisations and its impact by the actors.

Moreover, this research has contributed to presenting a business case for capacity-sharing solutions for the sector and presenting an artefact displaying the trade-offs for the parties for these solutions. Also, the gain-sharing mechanisms were devised for the sector based on calculative assumptions for supply chain costs and could be considered a contribution to the research for the sector.

However, in conclusion, the real impact of the interactive session could not be evaluated due to the non-availability of industry players in the session. This posed as a limitation of the project in addition to the assumptions utilized in the cost calculations divert the project from real values representation though this could be modified as per a real project.

Moreover, for further research, an iteration of this session could be adapted to either calculate indicative costs for a real project or develop a serious game with simpler values but more system inter-plays in the session. Since, the prototype in the research is a low-tech product, the former way could be easily adapted by modification in certain values. Also, the output values of this research would serve as a scale-up indication for the serious game development.

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Chapter 1

Introduction

According to the United Nations (2018), 55% of the total population resided in cities by the year 2018. This number is predicted to grow to about 68% by 2050 (United Nations, 2018). With the increase in urbanization, the demand for necessities such as food and shelter also rises. This will require new construction around the cities and maintenance or renovation of older establishments to accommodate more people. This would eventually result in high freight movement of construction vehicles through the city centers that lead to increased traffic congestion, safety hazards, air pollution, and noise pollution (Guerlain, Renault, & Ferrero, 2019). On the other hand, a Green Deal has been signed by 35 municipalities in the Netherlands to reduce the carbon emissions of urban logistics to zero by 2025 (Green Deal ZES, 2016). The policy would entail entry bans for vans in the inner-city areas by 2025 (Green Deal ZES, 2016). The vans are the most widely used mode of transport in the construction sector and contribute to the highest emissions in the urban sector (CE Delft, 2016).

Furthermore, the construction sector faces challenges in organizing supply flows to the construction sites. This is due to the complex nature of the supply chain in a project consisting of multiple parties such as clients, main-contractors, suppliers, and logistics providers that work temporarily for the span of a project (de Bes et al., 2018). Each of these parties suffers from the consequences of organizing logistics for the sector. Due to lack of detailed planning and complex inter-dependencies, the suppliers face uncertainties to balance their production and inventory for supplying to the construction sites. To respond to the adhoc demand, the suppliers often maintain high buffers at their side (de Vries & van Duin, 2021). The transport companies are generally involved at the last stage of the planning. Thus, these companies have to contend with only 30% of their full truckload capacity due to unstructured communication and unclear requirements from the parties (de Vries & van Duin, 2021). Also, the construction sector suffers from issues of low efficiency, high waste generated at sites, and delays in the construction process (Navon & Berkovich, 2006).

The aforementioned reasons pose an ardent need for the Dutch construction sector to adopt sustainable practices in the chain. Various researchers such as Melo, Macedo, and Baptista (2019), Janné and Fredriksson (2019) and Tezel et al. (2020) have tried to explore solutions in order to streamline the activities of the sector. One such solution is setting up construction hubs or construction consolidation centers (CCC) in outer city areas to allow bundling of materials and regulate the flow of construction logistics-related vehicles in the inner city limits (*D6.1_ Report on good practices in the EU and USA - SUCCESS*, n.d.; Janné & Fredriksson, 2019; Guerlain et al., 2019). Thus, it allows for better coordination and collaboration of flow of materials in the hard-to-reach inner-city construction sites (de Vries & van Duin, 2021; Janné & Fredriksson, 2019). Many sharing economy platforms allowing rental and leasing services for construction vehicles and specialized construction personnel are also introduced in the USA and few European countries (Li, Ding, Cui, Lei, & Mou, 2019). But these collaborative solutions are partly acceptable by the SMEs in the sector due to the high costs of such arrangements (in case of CCCs) (de Vries & van Duin, 2021), non-transparent conditions of sharing

equipment (Li et al., 2019) and unclear earnings models of these solutions (de Vries & van Duin, 2021).

In the logistics industry, sharing economy concepts are considered recent disruptive developments. According to Gesing (2017), sharing underutilized production resources in the chain could lead to social and economic benefits for the chain as well as surroundings in terms of lower congestion and emissions (Gesing, 2017). Following these concepts, TKI Dinalog has set up research in five domains in collaboration with the RDM Centre of Expertise:(1) City Logistics (2) Construction Logistics (3) Service Logistics (4) Transportation and Warehousing, and (5) Healthcare (TKI Dinalog, 2019). This research is part of the Construction logistics package. This study focuses upon three sub-areas of the domain namely:(1) Suppliers (2) Transportation companies (3) SMEs as they form an integral part of the construction sector.

In this regard, Rotterdam University of Applied Sciences (RUAS) has undertaken multiple projects to educate the SME stakeholders in the construction sector for the adoption of collaborative practices in the sector utilizing multiple embedded case studies approach (de Vries & van Duin, 2021). Interviews were conducted at supplier companies, transport companies, construction companies, municipalities, and digital platform providers to determine the challenges and barriers for adoption of collaborative practices by the actors (de Vries & van Duin, 2021). The below table 1.1 provides the documented sources with the interview research. The participating companies range from large construction companies who act as clients for SME companies to SMEs in the construction sector that specialize in certain activities or materials. In addition, quantitative data has been collected with the builders, suppliers, and transport provider companies for frequency of adhoc deliveries and lead times for delivery in the construction sector (de Vries & van Duin, 2021). The adjoining research to the project concludes towards the restrictive nature of the parties in the chain towards collaborative solutions and the need for raising awareness for profits and trade-offs for these possibilities in the chain (de Vries & van Duin, 2021). Therefore, this project is aimed to design a collaborative session that enables experiential learning for the interoperability of these solutions.

Table 1.1: Sources for stakeholders´ interviews

Interviewed stakeholders	**Source**
Suppliers	Kloosterman(2020) ¨ Testing the concept of sharing at suppliers to small and medium construction sites in the Netherlands¨
Construction companies	Hoogenboezem (2020) ¨Testing Sharing Economy in the Dutch Construction Sector with a focus on Small and Medium Enterprises active in civil and utility construction¨
Transport providers, Municipality of Rotterdam, Research group- ABN AMRO and Platform economy providers	Molemaker (2020) ¨Sharing in the construction industry: Towards a more sustainable and efficient supply chain¨

1.1 Problem Description

The stakeholders in the construction industry such as suppliers, construction companies, and transport companies experience many issues in organizing site logistics. The problems include un-coordinated delivery planning among the stakeholders (Olthof, 2018), inadequate material quantities and types (de Vries & van Duin, 2021; Navon & Berkovich, 2006) and non-full truck capacity movements to and from construction sites (CIVITAS, 2016). Smaller construction sites pose limitations for site storage of materials due to limited or no capacity and theft issues (Balm & Ploos van Amstel, 2017).

Consequently, the construction sector suffers from unnecessary vehicle movements, project delays, low productivity at sites (Bankvall, Bygballe, Dubois, & Jahre, 2010) and unnecessary waste generation (de Vries & van Duin, 2021) that ultimately adds to the costs of the project (Macharis, Turcksin, & Lebeau, 2012). Moreover, some municipalities also pose restrictions to the entry of heavy vehicles such as material-carrying trucks of construction sector (Macharis et al., 2012).

Along with the aforementioned constraints, the environment also poses challenges to the construction sector. The construction sector contributes to the highest movement of vehicles and is a leading contributor to the Urban freight transport (UFT) emissions (CE Delft, 2016). New policy introductions aimed at zero emissions attainment for companies and municipalities (Green Deal ZES, 2016) are posing an urgent need for the sector to enable better coordination and collaboration in the vehicle movements.

According to Baalsrud Hauge et al. (2014), production resource sharing is the solution to deal with these problems in the chain. One such sharing concept utilized is sharing economy business models. The definition of sharing economy is quite vast and is required to be narrowed down for the construction logistics scope. Reviewing the problem scope of sustainability and reducing congestion, the sharing of underutilized assets could be suitable in this case. Thus, the definition of the shared economy where "the focus is on the sharing of underutilized assets, monetized or not, in ways that improve efficiency, sustainability and community"(de Vries & van Duin, 2021; Rinne, 2017) would be used for the scope of the project. The applicable solutions include quantity verification and bundling of materials outside the city (known as construction consolidation center) (Janné & Fredriksson, 2019; Guerlain et al., 2019; *D6.1_ Report on good practices in the EU and USA - SUCCESS*, n.d.), platform economies offering rental and leasing solutions for sharing underutilized assets such as equipment or specialized personnel (Li et al., 2019), synchromodal transportation possibilities (Giusti, Manerba, Bruno, & Tadei, 2019) and smart governance and collaboration tools like 4C (Balm, Berden, Morel, & Amstel, 2018) for synchronized delivery and material planning. But these solutions have not been adapted to the full potential in the industry. The construction sector comprises of SMEs that possess expertise in specific activities or materials (de Vries & van Duin, 2021). Due to this, the construction supply chain becomes highly fragmented and complex (Briscoe & Dainty, 2005). Additionally, each project is one-of-a-kind and coordinating with the all actors is a hassle for the contractors. Furthermore, the SMEs are reluctant to adopt these solutions since the trade-offs and costs of these solutions are unclear for them (de Vries & van Duin, 2021). Moreover, organizing big construction hubs or new ICT systems entirely requires high costs and becomes difficult for many SMEs in the sector (de Vries & van Duin, 2021). Also, even for larger construction companies, due to high inter-dependencies (Bankvall et al., 2010) and inefficient planning schedules, these solutions currently have less impact than intended (de Vries & van Duin, 2021).

The various actors in the construction logistics chain also possess different interests and preconditions for the adoption of sharing business models in the sector as summarized from the interviews of the adjoining researchers of this project de Vries and van Duin (2021). These interviews were directed to understand the business model canvas for the involved companies. A business model canvas comprises of nine elements such as customers, key activities, products, cost structures, value proposition, customer relationships, channels and resources (Osterwalder & Pigneur, 2010). Since the overall project is focused on sustainability concepts and part economy sharing models, hence the interviews were directed in this direction.

According to de Vries and van Duin (2021), the builders view cost opportunities in increased productivity in the construction activities. Their major requirement is the availability of people, material, equipment, and knowledge at the right time on the site. They view the sharing opportunities in sharing capacity for materials, equipment and people (via shuttle buses) with main interests to tackle climate regulations of 2025. But these solutions are possible if there is adequate information sharing in the chain. The

unstructured planning activities and uncertainties in the construction sector add to these complexities and hence rush orders are required at sites often. But the suppliers offer rush delivery options as part of their business models. This is especially important for the small suppliers to be competitive in the business. This hinders the adoption of sharing concepts in the chain. Moreover, the suppliers are reluctant to share data on their activities which was evident in the interviews and their low participation in the questionnaire. For effective data sharing among the suppliers, their demand is a neutral party coordinator to facilitate these sharing solutions. Additionally, the transport companies in the chain also suffer from non-full truck load capacities. Most of the deliveries to the sites are made in the afternoon for the material requirement of the next day. Thus, the delivery schedules are generally full in the mornings and relatively free in the evenings. Also, the variety of non-combination goods such as liquid, oversized, bulk, etc. lead to increased difficulties in their combination. These companies also view opportunities in the sharing concepts and agree to be the director for the chain to regulate the flow of goods. (de Vries & van Duin, 2021)

Hence, the adoption of sharing solutions in the chain would result in different trade-offs for each actor in the chain. The solutions required for the SMEs need to be mindful of the requirements of the different stakeholders and the preconditions posed by the nature of their activities. These sharing solutions precondition collaborative practices in the chain but the trade-offs presented by the solutions are required to be tackled by each party through collaborative interaction and increased openness towards these solutions.

1.2 Problem Statement

As summarized in section 1.1, the collaborative challenges faced by the construction industry hinders its ability to adopt the sharing concepts in the chain. Thus, even though there are solutions prevalent for sharing concepts in the sector, their adoption is low by the actors. Introduction of greener policies by the municipalities also raise an ardent need for adoption of these practices (Green Deal ZES, 2016; Le Blanc, 2020). Hence, there is a need for encouragement of adopting these solutions collaboratively in the construction chain to better prepare the SMEs in the chain for the upcoming challenges.

According to Baalsrud Hauge et al. (2014), an experiential learning could promote openness towards collaborative practices in a supply chain. One of the methods that the author suggests is via serious gaming that depicts the systems interoperability of various trade-offs a stakeholder makes while sharing resources in a chain (Baalsrud Hauge et al., 2014). Many serious games are utilized in the supply chain sector for facilitating learning of complex decision networks for instance the ¨Beergame¨ where the challenges of bullwhip effect could be learnt via gaming via costs and benefits of each action (Baalsrud Hauge et al., 2014). According to Hofstede (2006), these supply chain games could be called ¨simulated networks¨ and though they represent a simplified version of the reality, ¨their necessary message usually goes across well¨. Building upon a similar idea, an experiential learning could be constructed for different players in the chain that facilitates discussion & allows the players to explore sharing possibilities & its realistic impact via trade-offs and business case in integration with gaming elements.

1.3 Thesis Project Objective

Based upon the problem statement above, the thesis project objective is constructed as follows:

Design and evaluate an interactive session that facilitates discussion and creates awareness in order to encourage openness towards sharing possibilities for SMEs in the construction logistics sector

1.4 Thesis Report Outline

The thesis report follows a particular step-by-step approach to attain the objective of the thesis. The figure 1.1 depicts the outline of the thesis and the outcome of each chapter is mentioned in colour.

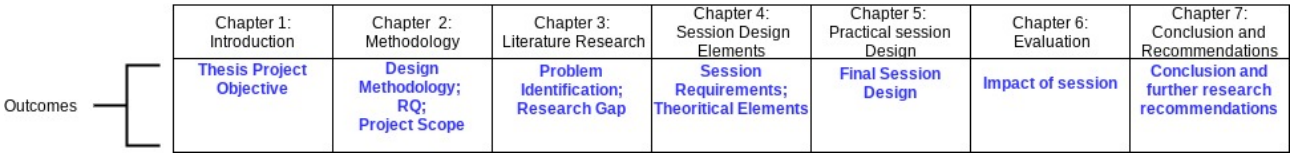


Figure 1.1: Report Outline

The report starts with an introduction chapter 1 summarizing the problems of the sector and actors in the chain resulting in the formulation of the thesis project objective. The Methodology chapter 2 builds upon the thesis objective and derives main research question and sub-research questions for attainment of the objective. The design framework for the session is established in this section that details the methodology followed in the thesis project. The project scope is defined for the thesis in this section that would set as a basis of research focus for the next chapters. The Literature Research chapter 3 explores the problem in-depth and summarize the challenges and research gap that needs to be addressed by this project. The Session design elements chapter 4 identifies the theoretical requirements of an engaging session design followed by stakeholder requirements of elements that need to be represented in the session. The chapter 5 operationalizes the requirements derived in chapter 4 to attain a practical session design. The evaluation chapter 6 depicts the impact of the session on the participants and eventually test the effectiveness of the project. The last chapter 7 Conclusion and Recommendations summarizes the entire project approach with research question answers and scientific contribution concluding with further research recommendations.

Chapter 2

Thesis Project Methodology

This section contains the methodologies utilized in this thesis project. The design methodology of the session and research question methodology has been established in this section. The section also presents the deliverable for the evaluation of the project in addition to the scope of the project that defines the specific research areas for the project.

2.1 Research Question Methodology

The attainment of the objective established in the section 1.3 requires an in-depth analysis of problems of SMEs from the sector followed by the appropriate solutions and session design and its impact evaluation on the participants.

Main Objective: Design and evaluate an interactive session that facilitates discussion and creates awareness in order to encourage openness towards sharing possibilities for SMEs in the construction logistics sector

In order to attain the objective identified for this project, a 5WH methodology proposed by Isaksen, Dorval, and Treffinger (2010). The methodology proposes an approach to problem solving by deep-diving into the problem and deriving the right parameters for problem approach. For this project, the 5WH is constructed and depicted in the figure 2.1.

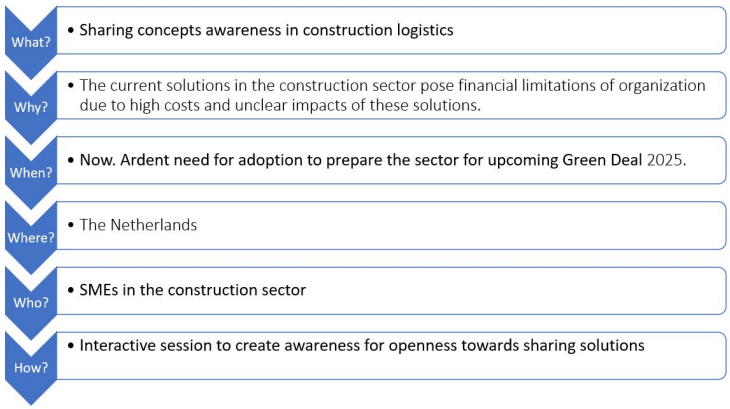


Figure 2.1: Research question methodology

An abstract version of the approach is summarised in the research questions formulated for this project. The 5Ws in the figure are comprehensive to the problems of the sector. However, the 1H question derives the solution approach and alternatives for the problem, thus, pointing towards the design objective of this project. These questions serve as basis for the sub-research questions of this research. Research sub-questions:

RQ1: What are the current challenges/ bottlenecks for SMEs in construction logistics ?

RQ2: What are the session requirements that would be utilized for raising awareness for sharing concepts in the construction logistics chain?

RQ3: Which sharing solutions would be appropriate for the SMEs in the construction chain?

Design Objective(D.O.): How to design and evaluate the interactive session that raises awareness of sharing concepts for SMEs in the construction supply chain?

RQ5: What was the impact of the session on the participants?

The RQ1 would address the current problems faced by SMEs and could be derived from an in-depth analysis of literature sources. The RQ2 and RQ3 concern the requirements of an effective session representing the choice of solutions to be represented and theoretical requirements of experiential learning such as to achieve the goal of this project. The Design Objective(D.O.) is related to operationalizing the session requirements to design and evaluate an interactive collaborative session for the participants. The evaluation part is an extension to the RQ5 that establishes the final impact of the session on the participants against the goal of the research.

2.2 Design Methodology

The session design methodology utilized in this project is a combination of five-step prescriptive design proposed by Dym, Little, Orwin, and Spjut (2009) and Triadic Game Design by Harteveld (2011). The prescriptive design process is a general product design comprising of multiple feedback loops that allow arriving at a verified product that serves the objectives of the project (Dym et al., 2009). Furthermore, each step output in the model serves as an input to the next step in the design process (Dym et al., 2009). In regards to experiential learning, according to Kolb (1984) it is defined as "the process whereby knowledge is created through the transformation of experience". Serious games have been used as the means of experiential learning in educational purposes for simulating reality concepts (Gouveia, Lopes, & De Carvalho, 2011). Triadic game design is a design philosophy that provides designers with a way of thinking for the right level of inclusion of elements (Harteveld, 2011).

The general prototyping process of a general product design with the technicalities of design thinking using design elements selection methods research and implementation are utilized for the construction and evaluation of the required session. The session deliverables are similar to a game design, however, given the realistic requirements of financial costs and benefit calculation for the session limits the use of gaming elements in the session.

As depicted in the figure 2.2, the components of triadic game design are incorporated into a general product design process to obtain the final session design with the required components.

The design steps and their functions are presented below:

- **Client need**: Design and evaluate a session that raises awareness for the openness towards sharing possibilities in the construction supply chain by facilitating discussion for the main stakeholders of the chain by providing qualitative & quantitative trade-offs for the project.
- **Problem Definition**: The interviews and the data obtained over functioning of the industry would be assessed to understand the current problems for the SMEs in the construction supply chain such that appropriate session could be designed for the chain.

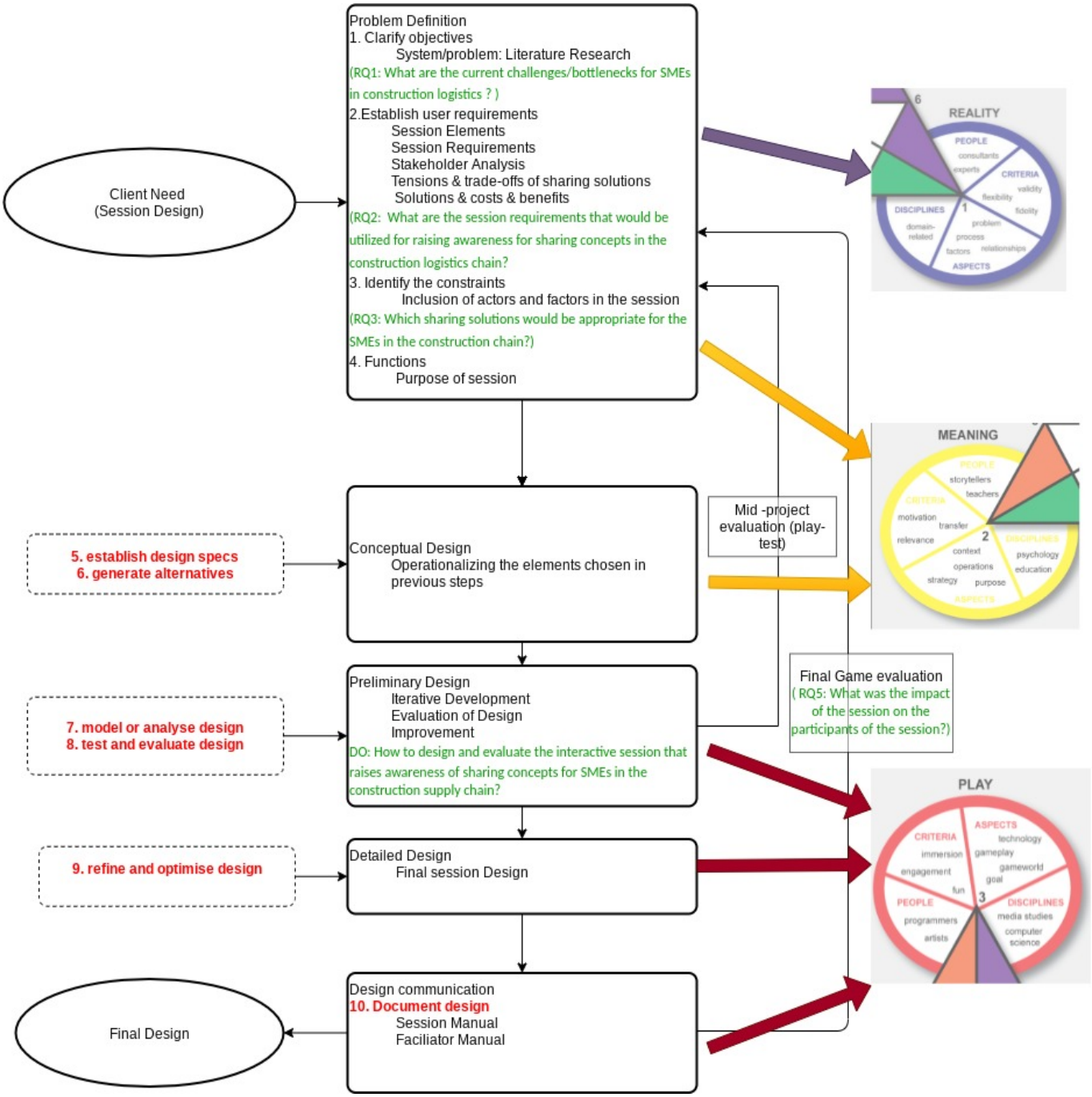


Figure 2.2: Thesis Design Methodology

- **Establish User Requirements**: Based upon the problem definition, the session requirements would be derived to match the research objective. These requirements would then need to be connected to the real world by understanding the factors and relationships of actors in the chain. According to Harteveld (2011), this includes the stakeholders in the chain & associated reality factors related to the problem such as tensions & trade-offs associated with sharing solutions in the chain.
- **Identify the constraints**: Since the game represents certain elements of the reality world, it is important to determine the constraints or inclusion criteria and limitations of gamification. The criteria of reality involve :
  (1)Flexibility: This elaborates upon the different aspects of reality depicted in the game.
  (2)Fidelity: This elaborates the extent of reality that is represented in the game.
  (3)Validity: This item elaborates if the reality is correctly depicted in the game.

- **Functions**: This section aims to define the functions of the session to attain the needs of the clients. The functionalities of this collaborative session involve learning of sharing concepts in the chain and improved understanding of the implications of these solutions. This could be measured via the times a collaborative solution is preferred by the participants in the game vs the business-as-usual (non-sharing) solution.

- **Conceptual Design**: The conceptual design would derive the appropriate specs for the product and the alternative technology platforms would be explored. Translating into the Meaning sheet deliverable for triadic game design: a strategy for the session design is formulated to reach the appropriate design. A series of established collaborative session examples such as games, frameworks and theories would be evaluated to determine suitability to reach the purpose of the required session. The operations would take a quantitative approach for the strategy implementation in the session. Thus, it is important to determine the right mechanisms that correspond to the value of the session. The last element is Context wherein the setting of the session is determined such as the target group, interplay medium, and additional elements required for the session. Additionally, gaming elements could be added to make the interplay competitive & engaging for the participants.

- **Preliminary Design**: In this phase, a session prototype would be made in multiple iterations to verify the determined requirements for the session. The mechanisms involved in the session would be tested & evaluated for their objective and quality along with subject matter experts from the industry to verify if the session can impart the required awareness to the industry players. The evaluation & feedback from this session would act as an input for the final session design targeted for industry players.

- **Detailed Design**: This step would entail the final session design incorporating the feedback from the previous step. The session would be finalized with the storyline, challenges, rules, and context for interplay. The technology required for the session needs to be determined such as any hardware or software required to participate in the session.

- **Design Communication**: The manual for the play session would be made to summarize the overall session interplay and the corresponding rules for the players. This would communicate the session design and its usability to the players.

  A final evaluation of the improved design from the previous phase would be performed to determine the impact of the session on the participants.

- **Final Design**: The above steps result in a final session design that would be utilized to raise awareness for openness towards sharing possibilities in the construction supply chain via experiential learning.

2.3 Project Deliverable

The project deliverable would be a match to be objective which is to develop and evaluate a collaborative session for raising awareness for sharing concepts in the chain. This would be done to facilitate discussion among the actors in the chain and adopt these solutions collaboratively in view of qualitative and quantitative business cases presented to encourage an informed decision for all parties. The main deliverable would be to communicate the sharing concepts in form of learning of the session to the participants.

Low ambition deliverable: The session presents participants with a business case for solutions with feasible assumptions to raise awareness & facilitate discussion among players.
High-ambition Deliverable: The participants provide feedback to implement these solutions in a real-time project in the construction sector.

2.4 Project Scope

The aim of the project concerns raising awareness on the collaborative solutions in the construction logistics chain. Given the problem definition in the sector summarized in section 1.2, the sector is aware of the logistics sharing concepts in the chain, however, the trade-offs and impacts of these solutions are not yet explored. Thus, this project aims to identify the factors that impact the stakeholders included in this research but these factors would be limited to certain quantitative and qualitative measures. The impact of change in ways of working embraces multiple impacts for companies such as training, new competencies in the sector, hiring processes, etc. and inclusion of all factors may lead to extended research time and complexity. This project was conducted in a time frame of approximately 7 months with means of literature analysis and design framework to achieve the set goal of the thesis. The main research was focused upon the qualitative analysis and quantitative analysis presented in adjoining master thesis projects of this project summarized in table 1.1. These interviews and surveys were restricted to few companies based in the Netherlands and might even pose restrictions in generalizability to different geographical locations due to different mobility solutions and policy introductions. The construction sector follows low logistics innovations as compared to other UFT sectors and hence, the approach of the project has been restricted to collaborative capacity-sharing practices in the chain and the focus on SMEs restricts these solutions to mostly public-body organized solutions. Also, in order to reduce the complexity of the session, a limited number of solutions and their impact will be presented in the project to allow participants to construct a deeper understanding of the presented solutions rather than being distracted by a multitude of solutions.

Having identified the methodology and scope for the project, the step-wise approach is followed in the next chapters starting with a theoretical approach of establishing user requirements.

Chapter 3

Literature Research

The section presents an in-depth analysis of the construction sector and current supply chain challenges of the sector along with specific challenges for SMEs. Furthermore, literature study is performed to understand he shared economy models that would be used to base the solutions for the construction logistics challenges faced by SMEs in the construction sector.

3.1 Urban construction logistics

3.1.1 Definition

The definition of construction logistics was proposed by TNO as: "the scope of construction logistics concerns all supply and disposal shipments of building materials, construction equipment and construction personnel to and from the construction site."(Quak et al., 2011; Balm & Ploos van Amstel, 2017). The scope of this definition clearly mentions the types of overall activities important for construction logistics. But the construction activities require precise quantity and time of delivery of resources due to the constraint of space and theft problems at construction site (Balm & Ploos van Amstel, 2017). This nature of the construction sector leads to ad-hoc deliveries and excessive movement of vehicles in the surroundings leading to excessive freight movement. Hence, for the purpose of this project, in addition to the definition above, the scope is broadened to the right amount and timely resource supply and disposal of materials, construction equipment and personnel to and from construction sites.

3.1.2 Problems in Urban construction logistics

In the urban context, many studies has been conducted involving urban freight transport(UFT) effects and sustainability but most have focused upon the retail and e-commerce services (Guerlain, Renault, & Ferrero, 2018). But these impacts of construction logistics had been highlighted only over a few years. Dablanc (2011) reported that 30% of all tonnage carried in cities are related to construction industry. Also, CE Delft (2016) points out the effects of movement of the construction vehicles by attributing the largest share (24%) of CO2 emissions amongst the Dutch urban freight. The construction sector also report a productivity of only 20%, the least amongst all economic sectors (Balm & Ploos van Amstel, 2017). This is attributed to the high variation in requirement of the labour and machines at different times in the project. These insights point to an ardent need for revival of the construction logistics sector.

For these reasons, the general supply chain solutions suitable in manufacturing were applied to the construction sector. Few studies such as Akintoye (1995) and Tanskanen, Holmström, Elfving, and Talvitie (2009) have tried to check the feasibility of manufacturing solutions such as Just-in-Time and Vendor-Management Inventory in construction sector but the scope has been limited to corporate companies and long-term partnerships amongst the stakeholders of the project, which is rarely observed

to the case in construction projects. Koskela (1992) argues this by describing the heterogeneous nature of the construction industry in the sense of high fragmentation and temporary multi-organisation that prevent a regular material or information flow attainment for the sector.

Koskela (1992) has tried to derive the peculiarities of the construction industry that distinguished it from other economic sectors and require unique solutions. These peculiarities are summarized in table 3.1.

Table 3.1: Peculiarities for construction supply chain. Adapted from Koskela (1992)

Peculiarity	**Process control problems**	**Process improvement problems**
One-of-a-kind	No prototype cycles, unsystematic client input and Coordination of uncertain activities	No standardized processes in place. Long-term improvement plans are difficult to attain.
Site production	Uncertainties including external uncertainties of weather etc. and internal uncertainties of sudden layout change, varying level of productivity for workers, etc.	Difficulty of transferring improvement across sites solely in procedures and skills.
Temporary multi-organization	Information flow disconnects amongst the members of the organisation	Difficulty of stimulating and accumulating improvement across organization borders.

The main topic relevant to the discussion is the temporary multi-organization characteristic of the construction chain. This parameter has been focused upon in further studies and highlighted as the main concern of inefficient activities of the sector.

The construction industry also suffers from the problem of variability. Each project in the construction sector is different and may consist of different stakeholders based on local region or nature of materials required.

Most of the literature have concentrated upon the main actors of the construction supply chain: contractors, suppliers and client (Janné & Fredriksson, 2019; Macharis, Kin, Balm, & Ploos Van Amstel, 2016; Morel, Balm, Berden, & Ploos van Amstel, 2020; Emerson, Nabatchi, & Balogh, 2012) and tried to propose solutions to the collaboration and sustainable problem via collaborative governance models, hub network called construction consolidation centre(CCC) and use of third party logistics. Construction consolidation centres follow a hub model for construction logistics where the project stakeholders store their pooled resources at one place and the required quantities are transmitted as per requirement to the construction site (Janné & Fredriksson, 2019). A SUCCESS project is launched all over Europe to fund research project to adequately select the feasible CCC locations for sustainable practices (Guerlain et al., 2019).

Few articles have tried to incorporate the external parties such as public authorities and citizens as well. The interests and limitations of all stakeholders are derived and a feasible solution is obtained via simulation satisfying all parties (Macharis et al., 2016). Furthermore, case studies in construction logistics have also presented the detailed unique organisation related to the particular project to assess the logistics situation precisely (Ekeskär & Rudberg, 2016).

3.1.3 Supply Chain in Construction Industry

According to Towill (1996), supply chain can be defined as ¨a system whose constituent parts include materials supplies, production facilities, distribution services and customers linked via the feed forward flow of materials and the feedback flow of information¨. But according to Butković Lana Lovrenčić, Grilec, and Josip MikulicJosip Mikulic (2016), due to high degree of project variability and subcontracting in the construction sector, this definition is a bit more complex.

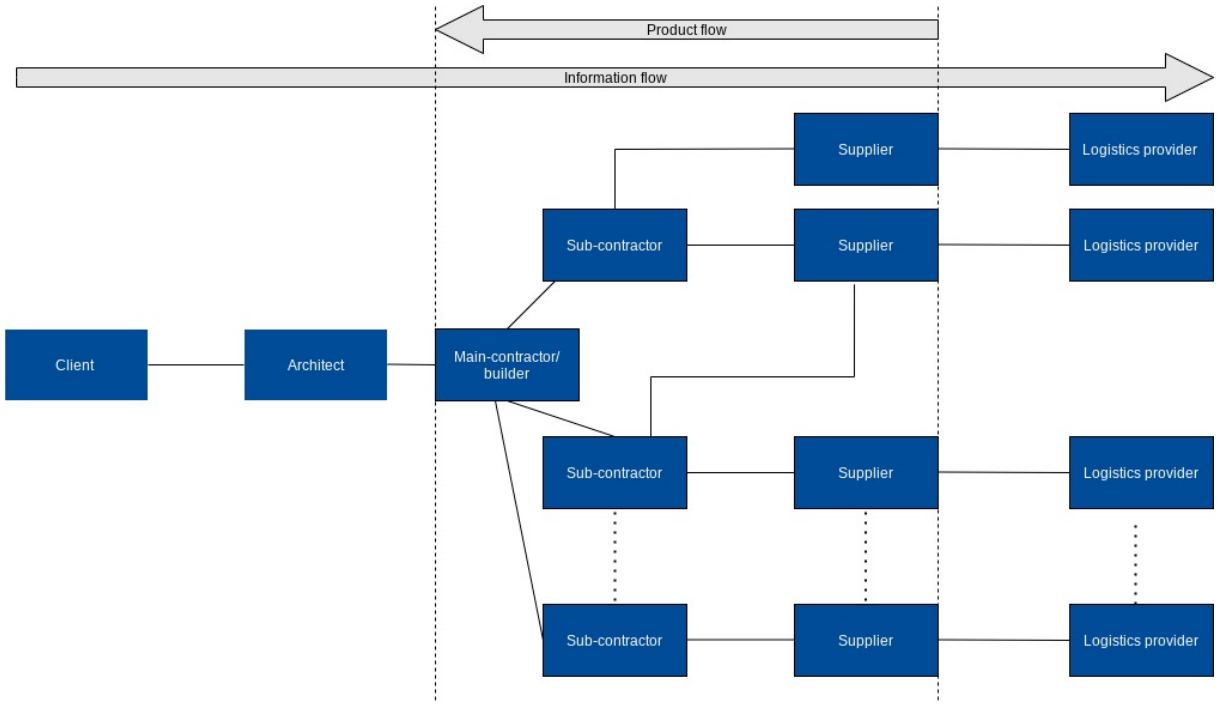


Figure 3.1: Construction Supply Chain. Authorś own depiction

The figure 3.1 depicts a typical supply chain in a construction project. The chain depicts the multitude of actors present in the chain starting form client body that initiated the project to the logistics provider of supplier contact that delivers the materials to the site. There are 2 types of flow depicted in the figure **??**: Product/ goods flow and information flow in the chain. The product flow is between the suppliers and sub-contractors that then report to the builder with a finished product/ raw material. A subcontractor could act as client to multiple suppliers or even two subcontractors in the same project could act as clients for the same supplier. The information flow refers to the design changes from the clients that flows in the chain as design change requirement and respective change in material requirement furthering to the transport delivery requirements to the site.

3.1.3.1 Relationship among stakeholders

The relationship between the stakeholders in the construction chain is loosely coupled and varies per project (Dubois & Gadde, 2002) which hinders innovation and productivity improvements in the sector. These loose couplings in the sector have also determined the relationship among the stakeholders that is based on a traditional single- stage competitive tendering wherein the customers have little control over price and is performed on contractual basis. The figure 3.2 depicts the types of loosely-coupled temporary relationships in the construction sector. As per the figure depiction, resources from A,B and C are working together on contractual basis on a single project meanwhile other resources from these firms are engaged in a different project as well depicted by A2, B2 and C2 respectively in the diagram. Furthermore, firm C sources material from firm D that indeed sources material from another firm E (Dubois & Gadde, 2002). Though these firms might establish long-term relationships but the temporary nature of the projects coupled with shifting requirements of material that may lead to

different handling types, equipment, etc. impair the inventiveness of the sector in logistics leading to low process efficiency and productivity.

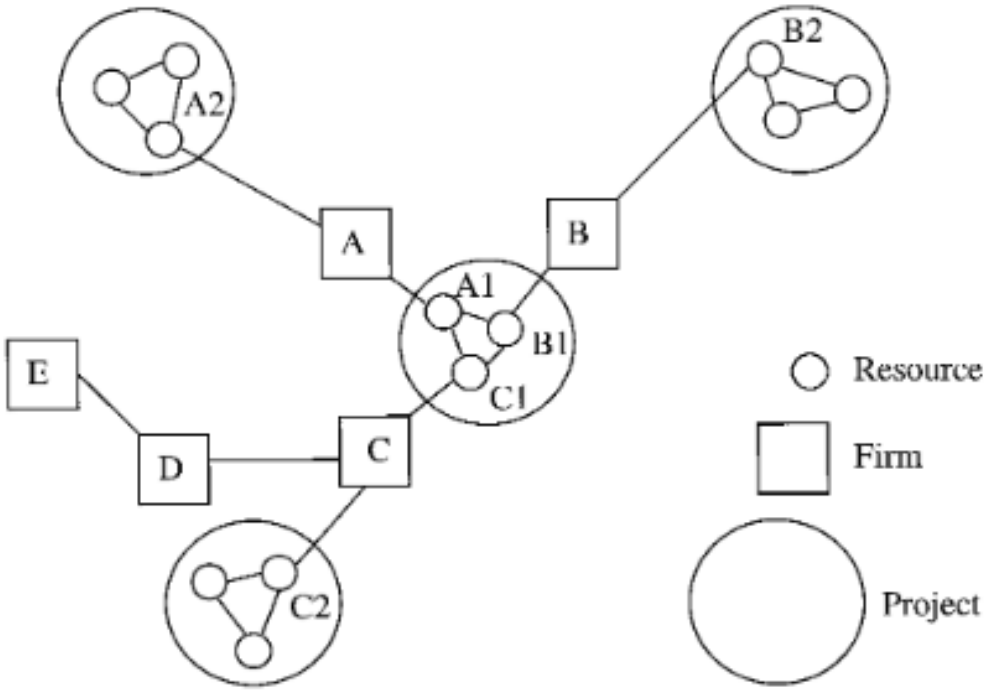


Figure 3.2: Loose couplings in construction sector. Reprinted from Dubois & Gadde (2002)

3.1.3.2 Construction Process

According to Klinger and Susong (2006), a typical construction process is divided mainly in five phases starting from concept/design phase to finishing phase as depicted in figure 3.3. A construction project starts with a client initiative who lays a demand for a constructed asset. After securing finance and necessary competence for designing and specification, a main contractor is selected in the next conceptual stage. The architect and main contractor determine the required design and appropriate materials required to execute the project. Tendering for procuring materials with the suppliers is implemented and required materials and quantity is specified for the materials. When contracts are finalised and a sufficient amount of delivery information is available regarding resource production and delivery, the physical execution of construction project can start. This includes delivery of materials on site, fabrication of elements and delivery of equipment and labour on site. Once a basic structure of the building is constructed and materials are made weather-proof, the finishing phase of the project commences wherein interior finishing such as doors, flooring, cabinet construction, etc. and electrical installations are installed. Once the work is finished, a handover process is executed and the building is handed to the client (Klinger & Susong, 2006).

Since this project concerns logistics of material handling process in the chain, the delivery process from supplier location to site is considered for optimization. The material delivery process is mainly in the construction phase that consists of mainly three phases: foundation phase, structural phase and finishing phase (Klinger & Susong, 2006). In foundation and structural phase, due to multitude of different materials such as sand, clay and pre-fabricated elements leads to low bundling possibilities for products (de Vries & van Duin, 2021). However, in the finishing phase, the goods are generally transported via pallets or in boxes to the site that could be combined for various project requirements and hence, open up the avenue of capacity-sharing in logistics for the construction sector (de Vries &

van Duin, 2021).

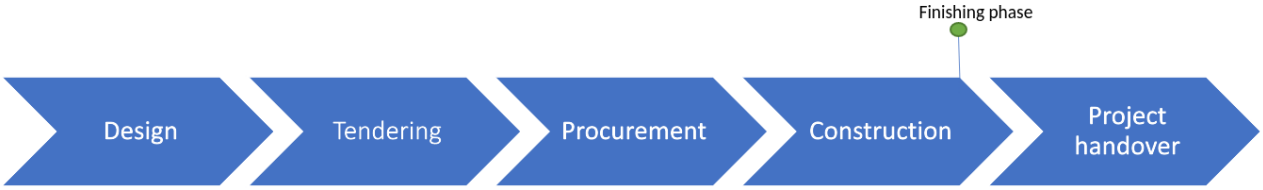


Figure 3.3: Phases in construction process

3.1.3.3 Supply flows in construction

According to Cox and Ireland (2002), a typical construction supply chain is a myriad of supply chains of material, labour and equipment supply chains. The labour and materials are directly delivered to the construction site whereas equipment is supplied to the professional services firms such as subcontractors specialised in particular construction activity (Cox & Ireland, 2002). Also, waste flows from the construction site is a downstream flow from site to the dumping grounds or waste processing factories (CE Delft, 2016). In conclusion, there are 4 types of supply flows at a typical construction site:

1. Material flow
2. Equipment flow
3. Human resources flow
4. Waste flow

3.1.4 SMEs' in construction sector and its associated problems

In addition to the aforementioned problems, the industry also presents a diverse range of specialist skills honed by SMEs in the sector (Dainty, Briscoe, & Millett, 2001). This leads to complex management of parties in a single project and has led to a proliferation in subcontracting that indeed further increased the fragmentation in the construction production process (Dainty et al., 2001).

SMEs stands for Small and Medium Enterprises and represent 99% of all businesses in the EU (*SME definition | Internal Market, Industry, Entrepreneurship and SMEs*, n.d.). An enterprise is classified as an SME if they fulfill the below conditions:

1. Staff count $<$ 250.
2. either turnover $<$=50 m or balance sheet total $<$= 43 m

A distinction could be made based on the above factors between SMALL and MEDIUM enterprises. The criteria is presented in table 3.2. According to the study conducted for UK´s construction sector,

Table 3.2: SME criteria

Company Category	Staff Headcount	Turnover
Medium-sized	$<$ 250	$<$=50 m
Small	$<$ 50	$<$=10 m
Micro	$<$ 10	$<$=2 m

SMEs comprise of almost 99 % of the total sector by 1998 (Dainty et al., 2001). Hence, SMEs make a crucial part of the sector and their inclusion for devising improvement solutions is necessary to for

increased efficiency of the solutions.

The adjoining case studies for the TKI Dinalog project has been conducted to understand the value proposition of these companies based in Netherlands. This had been done to analyse the current logistics model of these companies and propose appropriate solutions based on needs of the SME companies. According to de Vries and van Duin (2021), even though several innovations persist in the sector for improving the construction logistics performance such as use of Construction Consolidation centres (CCC), the limitation of organisation of these solutions has been restricted to bigger companies mostly. The SMEs in the sector had been deprived of these solutions due to financial limitations and unclear costs and benefits analysis for solutions available to them (de Vries & van Duin, 2021).

Due to the financial limitations of the existing solutions, the emphasis is laid of utilizing digital platforms and sharing of underutilized assets in the sector to improve collaborative consumption and shared costs via shared economy business models.

3.2 Shared Economy

Shared economy is an umbrella term used for organisational models that allow markets, cities, stakeholders to exchange, lease or sell goods and information to the interested parties (Mont, Palgan, Bradley, & Zvolska, 2020; Görög, 2018). It is a collective term used for models such as: collaborative consumption, freelance and gig economy, second hand economy, peer economy, access economy and product service systems (Görög, 2018). According to their definitions in the literature, shared economy could be classified under the collaborative consumption (Görög, 2018).

Furthermore, various researchers have determined the dimensions and characteristics that the described shared economy models are based upon. Frenken, Meelen, Arets, and van de Glind (2015) tried to establish a shared economy perspective different from on-demand economy(creating new demand for the goods such as requesting a new ride with Uber), second-hand economy(customers 2 customers access) and product-service economy(renting goods from company). According to Frenken and Schor (2017), this definition fits in the perspective of an pre-internet era where people shared goods with trusted partners only. But with the advent of ICT technologies, there had been a rapid increase in the exchange of goods amongst strangers with the reduction in transaction costs (Frenken & Schor, 2017). A second perspective on shared economy is provided by Acquier, Daudigeos, and Pinkse (2017) by resting the shared economy on core principles of access economy (optimizing use of underutilized assets), platform economy (facilitating exchanges using digital platforms), and community-based economy (co-ordinating through social networks or interactions). These perspectives were mostly based upon the peer-2-peer interactions.

3.2.1 Shared economy Business Models

In perspective of businesses, Muñoz and Cohen (2017) conducted a quantitative comparative analysis where four core factors (presence of technology, peer-to-peer interaction, under-utilized resources and the absence of collaborative governance) demonstrated strong causal relations for a business perspective whereas other dimensions including platforms for collaboration, a mission-driven approach and alternative funding did not demonstrate to be a strong driver for shared economy practices. Based on these outcomes, five business models were proposed for an shared economy solution adoption for companies:

- **Crowd -based tech Model** : This model combines core dimensions of Interaction and Technology and two peripheral conditions Governance and Resources. The applicability is generally determined in the traditional start-up environment that facilitate a peer-to-peer interaction. The business

model is dependent on network externalities on both sides of the platform. This business model could act as a facilitator only and not involve under-utilized assets .

- **Collaborative consumption** : This model combines core dimensions of Interaction, Resources and Technology and peripheral condition of Mission. It also facilitates peer-to-peer interaction with the core mission of inclusion of under-utilized assets, which is critical to shared economy structure (Frenken et al., 2015; Acquier et al., 2017). The example of Blablacar which facilitates under-utilized capacities at subsidised rates for long distance car-sharing is one such model. This supports the mission of promoting sustainability whereas not exploiting the customers by charging high private transportation rates (Muñoz & Cohen, 2017).

- **Business to crowd** : The model combines two core conditions of Resources and Technology and no other dimensions. It facilitates businesses via a technology platform to rent their privately owned resources to other businesses/customers to earn profits and ensure efficient use of resources. This model requires no to minimal interaction still promoting extant use of resources.

- **Spaced-based low-tech sharing** : The model combines none of the main factors and aims to facilitate low-tech resources such as workspaces. Most of the shared economy definitions focus on technological facilitators, but this model is considered a unique case in shared economy since such business models exist as well. The example of CoWorks organisation renting office workspaces follows this business model.

- **Sharing outlier** : The model combines core conditions of technology and interaction and peripheral conditions Funding, Mission and Governance. The non-profit organisations that enable technological interactions generally targeted for social upliftment but are funded by donations for its operations operate on this model. It is considered an outlier due to its rarity but the other conditions fit in the shared economic perspectives (Muñoz & Cohen, 2017).

Figure 3.4: Sharing business model compass. Reprinted from Munoz & Cohen (2018)

Furthermore, Muñoz and Cohen (2018) derived a compass for shared economy business models that provides input for crafting a business model based on six dimensions namely Technology, shared resources, governance model, business approach, transaction type and platform type. The shared

economy business model compass is depicted in figure 3.4. The four dimensions situated as concentric circles determine fundamental differences in the business model creation and shared value principles as the component more close to core is selected whereas the vertical components, Technology and Shared resources represent no distinct implication on the business model orientation (Muñoz & Cohen, 2018).

The six compass dimensions are explained in table 3.3:

Table 3.3: Shared economy compass dimensions definition. Adapted from Munoz & Cohen (2018)

Dimension	**Definition**	**Types**
Technology	¨Technology is defined as reliance on digital technologies for facilitating discovery and exchange on the platform¨ (Muñoz & Cohen, 2018).	Tech-driven (totally dependent on technology such as Uber); tech-enabled (platform for digital and face-to-face interaction) to low or no-tech.
Business Approach	¨Reflects upon the financial and impact objectives of the founding team¨ (Muñoz & Cohen, 2018).	profit-driven ; hybrid (firm demonstrates explicit social or environmental objective) to mission-driven (company´s goal is solely based on social or environmental objective).
Type of transaction	¨Extent to which transactions on the platform are left to market forces or altered by the intermediatery.¨ (Muñoz & Cohen, 2018).	Market (users dictate the value of products or services exchanged on the platform); Alternative (platform determines the value to the charged to either parties) to Free transaction (no fees incurred).
Shared Resources	¨Determining different origins of the resources shared on the sharing platform¨ (Muñoz & Cohen, 2018).	Optimizing use of new resources, finding a new home for used resources to optimization of under-utilized resources.
Governance Model	¨Approach adopted by platform with respect to decision making and value exchange¨ (Muñoz & Cohen, 2018).	Co-operate; Collaborative to Co-operative approach.
Platform type	¨Expression of the type of actors being connected in the two-sided market by the intermediary¨ (Muñoz & Cohen, 2018).	Business-2-Business; Business-2-crowd to Peer-2-Peer.

The shared economy compass is utilized in the interviews conducted as part of adjoining research of this project to map the appropriate domains for sharing solutions preferred by participants. This is depicted in figure 4.4.

3.2.2 Shared economy practices in construction logistics

The shared economy practices are slowly seeping into the construction sector as well. Digital platforms that allow peer-to-peer sharing of idle/underutilized construction equipment/personnel exist in some states in America, Finland China and Canada (Li et al., 2019). These applications facilitate sharing of idle material, personnel and equipment amongst the construction stakeholders. Li et al. (2019) performed an empirical study to determine the socio-technical impact on sustainability performance of these models. Sustainability performance was divided into three dimensions namely, social, economic and environmental dimensions and tested amongst the internal and external stakeholders of a project. The internal stakeholders were defined as stakeholders working on the same project such as contractors and subcontractors utilizing the same tower crane for their defined purposes. The scope of the study was limited to the Chinese construction industry.

The results of the study pointed towards the below phenomena:

- shared economy practices amongst the internal stakeholders had a positive impact on social, economic and environmental dimensions of the sustainability performance.
- shared economy practices amongst the external stakeholders had a positive impact on only environmental dimension (Li et al., 2019).

These results do point out the conduction of shared economy practices in the construction sector. The sharing of equipment or personnel in the internal projects are quite prevalent practices and facilitated via social ties. But the reluctance of sharing practices among the external stakeholders could be attributed to the information asymmetry in the digital platforms. According to Li et al. (2019), the lack of clarity for the shared policies in the form of contracts or clear terms and conditions has prevented many stakeholders to not to opt for this option. The uncertainty about the condition of equipment and the responsible party for its maintenance are also some of the listed concerns for low adoption of shared economy practices outside the project scope (Li et al., 2019).

However, the significance of social and economic capital in the external sharing practices is low. The motive of peer-to-peer transactions is not impacted by the social interaction or may not always lead to strong social ties. But the authors, Li et al. (2019), have argued the importance of right governance mechanisms in place to mitigate information sharing risks and promote the external interaction could be regarded as social dimension.

The reluctance of sharing practices complement the conscious nature of the companies in the sector. Hence, a suitable shared economy model and its importance needs to be established in the construction sector to promote effective utilization of resources and sustainability practices in the sector. According to Baalsrud Hauge et al. (2014),representing costs and benefits of shared use of resources in logistics to the stakeholders via experiential learning and its representative systems interoperability is the recommended way to do this.

3.3 Research Gap

The shared economy business models enabling efficient use of underutilized assets are emerging across all sectors. The most familiar examples include Airbnb in the tourism sector and Zipcar providing a shared car solution. However, the logistics sector has also been looking forward to these models to share truck-capacity and storage spaces in the sectors (Baalsrud Hauge et al., 2014). These solutions are effectively suggested for SMEs that are technically specialized but struggle to utilize logistics capacity due to low requirement of particular products owing to trends in customization and constantly shifting customer requirements. Moreover, this is certainly the case for SMEs in the construction sector in

Netherlands as well.

The construction sector owes its low efficiency practices to its temporary organisation nature that restricts innovation and partnering in the chain. The sector is dominated by SME companies that are conscious of behavioural changes in working and data-sharing practices due to their specialized nature. However, the upcoming Green Deal 2025 is posing an ardent need for these companies to adopt sustainable practices in the chain that aim to reduce emissions in the chain as well. According to de Vries and van Duin (2021), the sharing of truck-capacity could lead to decreased social and economic costs in the chain. Similar to other countries, the Netherlands market offers sharing solutions in terms of platform economies such as Transmission and Floow2, however their usability in the sector is low. As summarized in section 3.2, these solutions require collaborative practices in the chain but the SMEs are not aware towards the openness of shared economy practices in the chain. Furthermore, the section 1.1 also confirms this conscious nature of SME companies in the chain and a requirement for business case for such solutions impact. In order to implement these solutions in an efficient manner, the companies need to work collaboratively both vertically and horizontally in the chain. Thus, a collaborative understanding with trade-offs of each party needs to be established that facilitates discussion and represents trade-offs in the chain to increase awareness towards sharing solutions for parties in the chain. This collaborative discussion is decided to be co-operated in a session organised to present experiential learning for participants in the chain thus leading to achieve the goal of the research as described in section 1.3.

3.4 Conclusion of Literature Research

The section 3.1 provides in-depth analysis of characteristics and challenges of the construction sector and its SMEs. This aids in identifying the appropriate solutions for the SMEs in the chain and underlying requirements for those solutions. The section summarizes the appropriation of shared economy business models for combating the challenges for the sector. Next, the literature review conducted in shared economy business models in section 3.2 led to shared economy compass that depicts the various domains and their options for such business models for the sector. Similar sharing practices were found in other parts of the world for construction logistics sector however, these practices have found restricted use in the sector due to the unawareness of their impact for the financial and data conscious SMEs in the chain. Hence, a collaborative session facilitation is proposed to educate SMEs towards the openness of these solutions and their impact via business case.

Chapter 4

Determination of Session Elements

This section deals with the d of interactive session related to the theoretical requirements of a session, solutions to be represented in the session and business case to be displayed to the actors.

This section deals with the determination of elements required to formulate an engaging session in addition to the solutions to the

4.1 Session Requirements

This section represents the requirements of the session to be implemented for achieving the awareness of solutions in the sector.

The interactive session approach proposed for this project depicts an experiential learning with realistic business case values and easier adaptability for a real- time project. However, Baalsrud Hauge et al. (2014) suggests use of serious games to create the experiential learning required for depicting the advantages and limitations of shared resources in the chain. The serious games are games that involve learning along with entertainment by involving a simpler representation of reality (Hofstede, 2006). Due to this contradicting nature of the serious games, the researcher has chosen to design an interactive session with real values, however, to make the session more engaging some gaming elements are incorporated in the session. Thus, the below sections include literature relevant to gaming such that it could be included in the session.

According to Baalsrud Hauge et al.(2014), experiential learning could be utilized to create required understanding for the advantages and limitations of shared resources in a chain. By effectively sharing resources, both producers and suppliers will benefit in terms of less inventory, less transport costs and improved resource utilization along with reduced emissions, but flexibility of individual players is reduced. Less flexibility is experienced since the company priorities or offerings need to be in agreements with the collaboration partners. In addition, planning complexity and reduced freedom for decision- making process for organizations create trade-offs with implementing shared resources. Even organizational changes in terms of adoption of new ICT tools could create new competencies and might lead to organizational structure change. Furthermore, the limitation of sharing information among parties is related to lack of trust and type of information to be processed, also systems interoperability between different actors needs to be represented in the game. Due to multiple trade-offs, a multi-criteria system need to be utilized to depict the impact for stakeholders. An explicit gain- share split needs to be established at the beginning of model implementation leading to satisfactory quantifiable results for all parties and allowing for synergy gain calculation and redistribution of costs in the chain (Baalsrud Hauge et al., 2014).

4.1.1 Session type for gaming elements

According to Baalsrud Hauge et al. (2014), multiplayer games allow the players to experience the importance of collaboration and improved communication via information sharing and view the benefits in a more implied manner. It even allows collaborative discussions and different perspectives to be displayed in the game by the players facilitating discussion in the game. Hence, a multi-player game approach is chosen for this project. Another dimension of games is categorized in terms of strategies of players namely competitive, cooperative and collaborative games. Competitive games requires players to form opposing strategies to be the sole winner of the game whereas co-operative games provides a simulation wherein two players possess interests that are "neither opposed nor coincident" similar to the prisoner's dilemma situation (Zagal, Rick, & Hsi, 2016). However, cooperative games present different results in subsequent iterations and eventually are aimed at better collaboration though not all parties might win in this situation. Another category of games that was recently acknowledged is collaborative games. Collaborative games are the one where participants work as a team, sharing pay-offs and outcomes and the verdict of win and lose outcome applies to the entire team (Zagal et al., 2016). Collaborative games differ from cooperative games in regards with a single aim and rewards share in the team (Zagal et al., 2016) . A similarity can be drawn between collaborative games and a construction project where multiple temporary parties come together to strategize a particular logistics solution to be implemented in a project. The solution could be better implemented in cooperation with all parties and eventually benefit all parties in the chain. In order to design a collaborative game, a few game elements need to be considered. A tension needs to be introduced between the perceived individual utility and the team utility and must reflect payoffs made by players (Zagal et al., 2016). The game is required to bestow different responsibilities on each players and also include certain actions to be performed not in consent of the team. To promote collaboration, a sufficient rationale needs to be provided that produces a satisfactory result. The game must be able to produce different experience each time the players play the game (Zagal et al., 2016) . These characteristics of a collaborative game if modeled correctly might lead to a good level of collaborative game for the participants.

4.1.2 Flow of the session

Flow is defined as the "a state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will continue to do it even at great cost, for the sheer sake of doing it" (Csikszentmihalyi, 2014). The measurement of flow has been focused on gameplay wherein focused state of players were measured. Flow is based on 2 main conditions:

- perceived challenges stretching one´s skills.
- clear goals & immediate feedback leading to actions

A mapping was developed to assess perceived challenges versus the skills possessed by the players. Flow state is achieved when the challenges & skills are above the actor´s average levels according to the revised model. The original model developed by Csikszentmihalyi (2014) measured flow state as a balance of one´s skills and perceived challenges. The region below flow state was termed as boredom whereas above flow state was termed as anxiety. However, a revised model represented flow state as an above average achievement of skills and challenges and depicted in figure 4.1.

4.1.3 Assessment for gaming elements

According to Bellotti, Kapralos, Lee, Moreno-Ger, and Berta (2013), assessment mechanisms in a game are used to assess the players achievements and their learning skills. These mechanisms replace the traditional test in a regular training environment with a play-based assessment that allows for more detailed and reliable information to be extracted for the players. This is done via allocating points to every move or goal attained by the player that might increase with each level of difficulty. Another approach is calculation of points based on mechanisms or decisions taken by player in the game. This

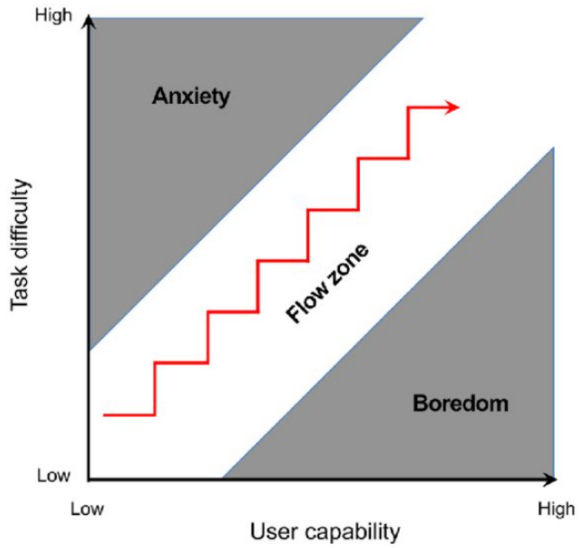


Figure 4.1: Flow zone. Reprinted from Csikszentmihalyi et al (2014)

is an effective approach since it integrates learning and games by providing progress feedback and aligning user adaptivity with each difficulty presented to them (Bellotti et al., 2013).

4.1.4 Scaffolding Mechanism

Scaffolding refers to the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving by an expert (Obikwelu & Read, 2012). The scaffolding mechanism is generally used for serious games education wherein just enough support is provided to the player in the learning process to achieve the expected learning outcomes. The scaffolds could be interaction among individuals, artefacts, resources or environments and are not restricted to these methods alone (Obikwelu & Read, 2012). A conceptual model for integrating scaffolding in the learning session is articulated by Obikwelu and Read (2012) that includes feedback, hints and de-briefing as depicted in figure 4.2.

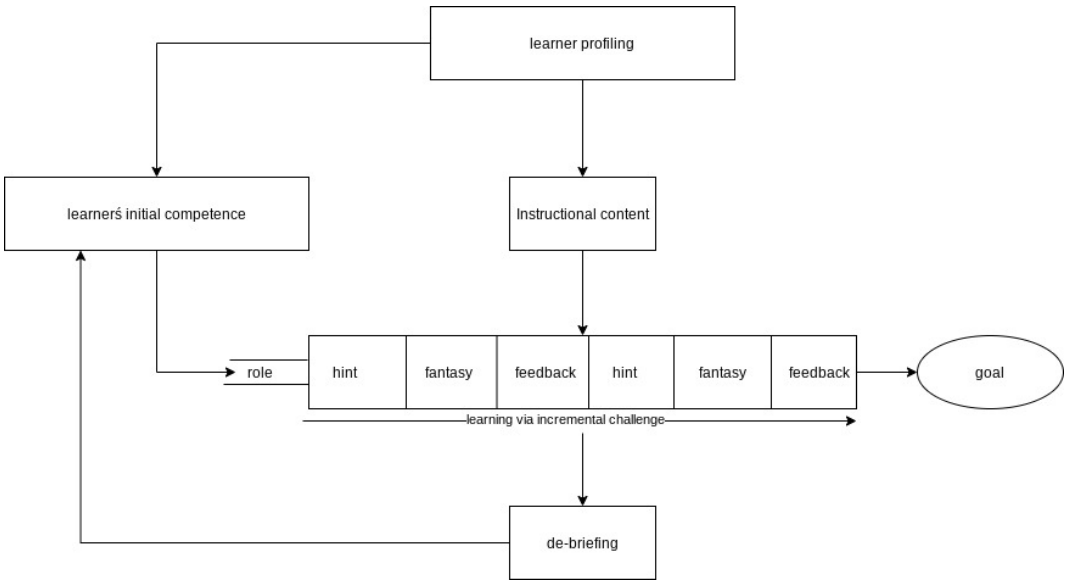


Figure 4.2: Scaffolding conceptual model. Adapted from Obikwelu & Read (2012)

In the model, learner profiling needs to done to determine the current knowledge of the participants is the first step of the process as it is important for the level of guidance required for the session. The players tend to look for hints and feedback to move forward as their assumed role in the game. The instructional instrument tends to provide these hints or feedback to the player and drives the learner to expand some effort and focus attention to the task. Next, the summary feedback in terms of points/ progression of the player in the game provides the teacher with an assessment of the performance. Lastly, a de-briefing is held by the teacher that entails feedback response based on the playerś performance in the game tendering to the focus points in the game. The re-entry in the game-play drives the student to draw from the knowledge acquired from the de-briefing and previous game-play and lead to a new acquired knowledge required for game progression (Obikwelu & Read, 2012).

Moreover, a concept of external scaffolding for serious games is also proposed by Barzilai and Blau(2014). An external scaffolding may be in form of pictorial representation or review and analysis of the game assessment in terms of graphs in the de-briefing. Also, a discussion connecting the reality to the gameworld could also be facilitated however, the impact of these external scaffolds had not been evaluated yet. Moreover, these scaffolds could also impact negatively and might shift the learners perspectives to the complexities of the real world rather than focusing on the simpler version of the game (Barzilai & Blau, 2014).

4.1.5 Summarizing requirements

Table 4.1: Requirements for Session Design

Session requirements	Need/ Nice-to-have	Source
Collaborative session for main stakeholders	Need-to have	Section 4.1.1 Baalsrud Hauge et al.(2014) "Collaborative Serious Games for Awareness on Shared Resources in Supply Chain Management"
Experiential learning via Scaffolding principle: hint-> fantasy-> feedback ->debriefing —-> goal	Need-to- have	Section 4.1.4 Baalsrud Hauge et al.(2014) "Collaborative Serious Games for Awareness on Shared Resources in Supply Chain Management" & Obikwelu et al ¨The Scaffolding Mechanism in Serious Games ¨
Multi-criteria decision-making systems to be represented	Need-to-have	Section 4.1.1 Baalsrud Hauge et al.(2014) "Collaborative Serious Games for Awareness on Shared Resources in Supply Chain Management"
External scaffolding to be applied (how to play the game) (play tutorial and what to learn)	Nice-to have	Section 4.1.4 Barzilai and Blau(2014)¨Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences¨
Challenges to increase in subsequent sessions	Need-to-have	Section 4.1.2 Csikszentmihalyi (2014) ¨Flow¨

Role-interchangability to be facilitated in the session	Nice-to have	Section 4.1 Harteveld, Guimarães, Mayer, and Bidarra(2007) " Balance between fun, game and pedagogy"
Game evaluation to be established: user questionnaire/ survey before and after game	Need-to-have	Section 4.1.3 Bellotti et al.(2013) ¨Assessment in and of Serious Games: An Overview¨
Costs and benefits of solutions to be represented in the session	Need-to-have	Section 1.2 Problem Definition
Tension between individual utility & team utility to be represented	Need-to-have	Section 4.1.1 Zagal et al. (2016)"Collaborative games: Lessons learned from board games"
Gain-share mechanisms to be represented	Need-to-have	Section 4.1 Baalsrud Hauge et al.(2014)"Collaborative Serious Games for Awareness on Shared Resources in Supply Chain Management"
Planning deliveries 2-3 days ahead to be encouraged for sharing solutions	Nice-to-have	Section 4.1 Stakeholder Discussion and interviews; Baalsrud Hauge et al.(2014)"Collaborative Serious Games for Awareness on Shared Resources in Supply Chain Management"

4.2 Stakeholder Analysis

Constructions sector by nature is considered as a project-based industry with its ¨one-off project¨ and pull approach (Behera, Mohanty, & Prakash, 2015). Mostly construction projects are unique in the sector due to different client requirements and employs many temporary partners in the project in contrast to process-based manufacturing industry.

According to Newcombe (2003), project stakeholders are groups or organisation that hold an expectation of the project´s performance. In a construction project, stakeholders include clients, project managers, designers, subcontractors, funding bodies, users and community at large. These stakeholders hold different powers that influence project decisions and is highly dependent on their attitudes and behaviours (Newcombe, 2003).

Projects are viewed as a multi-actor coalition operating in a system of multiple and often conflicting objectives. These conflicting objectives shape the bargaining process between the key actors that ultimately results in evolution of project strategy. Power and interest of each actor plays an important role in determining the direction & decisions of a project (Newcombe, 2003). These decisions could even be to enforce fundamental change for a project such as decision for collaborative solution.

Furthermore, stakeholders values could be divided in two arenas, namely cultural arena and political arena. Cultural arena concerns with shared values of the stakeholders that acts as a force for co-operation in the project whereas political arena acts when powerful individuals and interest groups try to push for their individual objectives that often conflict with those of other stakeholders (Newcombe, 2003). Its the interplay of these arenas that shape the discussion ultimately leading to a final strategy.

In perspective of construction projects, similar characteristics are observed where multiple temporary stakeholders exercise different powers and interests throughout the project span (Newcombe, 2003). With respect to construction logistics solutions, the actors involved in the project are generally decision-makers for the adoption of the solutions in the finishing phase of construction as per the project scope. A stakeholder analysis for a construction project that concerns decision-making for construction logistics solutions is presented in the figure 4.3.

A power-interest matrix approach is utilized here to demonstrate the power exhibited by each stakeholder for the decision concerning the organisation of construction logistics for the project. The stakeholders are divided into 4 quadrants:

- High Power- High Interest [**Manage Closely**]: These stakeholders are the decision makers of the project and have the biggest influence on the project decisions.
- High Power- Low Interest [**Keep Satisfied**]: These stakeholders need to be informed regarding the decisions of the project and could utilize their power that could lead to negative consequence if they are unsatisfied.
- Low Power- High Interest [**Keep Informed**]: These stakeholders need to be consulted or informed of the project decisions. Though these stakeholders could not influence the decision directly, the impact of these decisions could fall on them and hence they are interested in the project and their opinions could be utilized in detailing the solutions.
- Low Power- Low Interest [**Monitor Closely**]: These stakeholders need to be monitored, but do not play an important role in decision-making for the project and hence need not be informed constantly regarding the project progress.

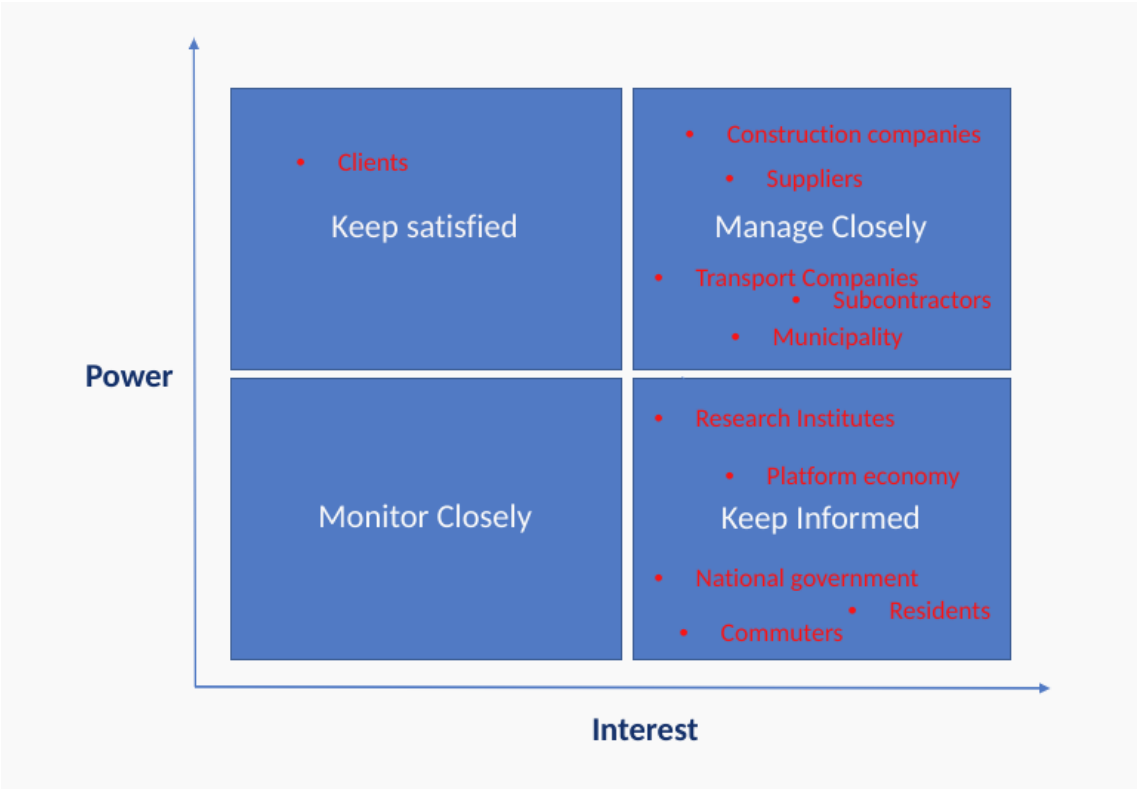


Figure 4.3: Power-Interest Matrix for stakeholders. Adapted from Newcombe (2003)

Table 4.2: Stakeholder Mapping. Adapted from Newcombe (2003)

Stakeholder	Power	Interest	Description	Reason
Builders Main-contractor	High	High	Responsible for execution of construction project.	**Manage closely**; the solutions would impact the margins of the contractor and may also take responsibility for the solution execution.
Sub-contractors	High	High	Commissioned to perform specialized work at the construction site.	**Manage closely**; Subcontractors are part of the solution and a decision would directly impact them, hence they hold high power and interest in the conduction of these solutions.
Material Suppliers	High	High	Supply the construction project with required materials and services.	**Manage closely**; Play a direct role in supplying materials to the site and would act as major players for the project execution.
Transport companies	High	High	Responsible for transporting construction materials and equipment to the construction site.	**Manage closely**; Play a direct role in supplying materials to the site and would act as major players for the project execution.
Municipality	High	High	Responsible for issuing permits and transport policies to promote livability in the city.	**Manage closely**; Before the construction project, municipality issues permit for parking and transport in inner-city areas and also their policies would play an important role in motivating the stakeholders to adopt collaborative solutions.
Platform economies	Low	High	Provide digital platforms for collaboration of underutilized resources.	**Keep informed**; Offers solutions for collaboration in the sector and their operations could scale up due to the adaptation of the platforms hence, they possess high interest.
Residents	Low	High	People who reside near the construction site.	**Keep Informed**; Emissions and nuisance from the construction site seems to impact the nearby residents and hence, they are interested in reducing these nuisance factors but they possess low power in terms of adoption of these solutions adopted for a project.
Client	High;	Low;	Project initiator and provides finance for the project.	**Keep satisfied**; Important to keep client satisfied in terms of timely completion of the project and staying within the specified budget of the project.

Stakeholder	Power	Interest	Description	Reason
Commuters	Low;	High	People who commute near the construction site.	**Monitor closely**; reduced number of vehicles from the construction site would positively impact the commuters in terms of reduced traffic jams and accidents but they hold low power for the adoption of these solutions in a project.
National Government	High	Low	National government that allocates funds to municipalities and participates in the transport policy discussions.	**Keep informed**; need to allocate budget to the municipalities and is responsible for the execution of Green Deal, hence even though they do not directly impact the solutions, their interest is high.
Research Institutes	Low	High	Responsible for devising solutions for the construction sector to meet policy demands for the sector.	**Keep informed**; Solutions discussed for reducing emissions are of interest to the research institutes.

The stakeholder analysis represented in table 4.2 depicts the various stakeholders that hold power and interest in different ways in influencing the construction logistics solutions implementation in a project. However, a necessary requirement for the session is implied to analyse the impacts on the high-interest and high-power players namely builders, suppliers and logistics provider parties in the chain. The other stakeholders could be depicted using other parameters in the business case impact representation such as emissions reduction and low traffic leads to better livability for residents and commuters. Similarly, the reduced emissions would also lead to the attainment of Paris Climate Agreement that stands on the agenda of national government and hence could be represented by reduced emissions. The research institutes and platform economy solutions could be depicted hold high interest in the solutions and would be directly influenced by the positive financial impact resulting in increased revenue due to high interest towards these parties. The clients holds high power in influencing the main stakeholders' decisions and would be directly impacted from the financial implications of these solutions. These finalised parameters for the business impact are summarised in table B.1.

4.3 Tensions & Trade-offs between players

4.3.1 Problems of the sector:

The construction sector is paralysed with many problems in terms of site storage space and efficient logistics that eventually makes them the most pollution contributing sector in Netherlands (CE Delft, 2016). The adjoining research of this project was focused on determining the business model of the main actors in the chain to understand the current state of construction logistics solutions in the sector. The interviewed participants included SMEs and bigger companies that either serve a clients or have clients as SMEs. The major issues highlighted that hinder the implementation of these solutions in the sector are:

- Payment for organisation of solutions : In most of the cases, construction companies take charge of organising the solutions and their funds need to be recouped within the project costs.
- The ad-hoc operations in a project lead to inefficiencies for construction logistics in terms of non-full truck load capacity but these rush orders are a part of business model for suppliers & carriers that charge extra commission for these deliveries. However, these parties do have to bear the additional costs due to high stock buffers on supplier side especially for Make to Order

(MTO) products and driving empty adds to the driver costs and fuel costs for the carriers. This points to the extra costs added due to the non- collaborative operations of the sector.

- A few builders also prefer take-away service at suppliers as it helps in establishing better relationships with the parties in the chain. This points to the behavioural changes required for the sector. But the restricted entry of vans in inner city areas might be helpful in restricting this behaviour and encourage more collaborative practices.
- Even though a few construction companies and suppliers offer construction logistics solutions such as construction ticket for scheduled arrival of trucks at site, but the use of these logistics solutions is limited due to non-transparency of costs & benefits associated and negative impact to service quality and increased operations and time.
- Parties are cautious regarding sharing information with their competitors in the chain though this is crucial for the implementation of construction logistics solutions.
- Increased productivity at site could be ensured in case of collaborative solutions due to availability of all supply flows at the site at once with regards to better planning and coordination due to collaboration (de Vries & van Duin, 2021). Better planning is also appreciated by suppliers in terms of reduced storage costs at the outbound side. However, the finishing phase is laden with uncertainties due to high inter-dependencies and a better planning schedule may not always be possible (Bankvall et al., 2010).
- Regulations over emissions and planning for obtaining construction permits such as BLVC (Bereikbaarheid, Leefbaarheid, Veiligheid en Communicatie) are driving the contractors to opt for environmental friendly solutions since the bidding phase itself (*What is BLVC? | BLVC*, n.d.).

These tensions and trade-offs obtained from the practical working of the construction sector set as pre-conditions for the solutions and need to be balanced for the solution inception for the project.

The stakeholders analysis in section 4.2 and tensions and trade-offs summarized in section 4.3 would serve as the basis of selection of actors and factors in the session. The determination of actors and factors is derived from the triadic game methodology of the methodology summarised in section 2 that leads the designer to identify the core design elements for the required product (Harteveld, 2011). The session design in chapter 5 will try to incorporate these elements and derive the appropriate elements for the session. The finalized parameters included in the session derived are summarized in table 5.5.

4.4 Solutions & associated Costs & Benefits

The solutions in literature were shortlisted on two main basis: Shared Economy mapping derived from adjoining research via interviews from the stakeholders & integrated solution approach for a project site.

4.4.1 Shared Economy Mapping

The construction logistics sector has been suffering from efficiency problems particularly due to site storage space shortage and inefficient capacity use for transport. Alike other sectors, these inefficiencies have led the sector to adopt multiple innovative logistics solutions. The main focus for these solutions has been to improve the information sharing in the chain and provide a space for organising logistics in the project and allow FTL shipments and required materials to the site. Many studies focused on these solutions leading to best practices in the sector.
In the Netherlands, multiple projects were initiated that utilized these solutions such as Hotel Amstelkwartier that used a hub with work packages and kits in alignment with integrated pre- planned work-schedule. Transport was managed via digital construction ticket system called Ilips and smart waste

returns wherein delivery trucks carried back waste downstream from the site. Another project was De Trip in Utrecht that implemented a construction hub for personnel, integration of transport planning in construction planning and appointment of construction logistics coordinator at hub and site in addition to the solutions utilized in the Amstelkwartier project. Subsequently, there are plans to develop a 4C tower to co-ordinate transport planning from the hub(s) in the upcoming years (van Merriënboer & Ludema, 2016).
Even though these solutions lead to reduced operational costs via supply chain improvement practices and reduced emissions in the chain, the organisation of these solutions such as building a hub leads to high demand of capital and human resources. These aspects are important since the construction sector comprises of mostly SMEs that are unable to organise these solutions solely. Hence, an approach for efficient use of resources such as truck capacity and assets with low costing business models need to be established. In addition, the policies regarding Green cities that aim to restrict movement of polluting vehicles in inner city areas would require a shift to cleaner fuel vehicles that could lead to financial burden for SMEs and even take-over by bigger companies (Molemaker, 2020). According to Soltysova and Modrak (2020), Sharing economy business models present a ¨promising challenge¨ for the SMEs. It presents a new economic thinking wherein resources are shared or borrowed instead of owned. SMEs have limitations in terms of securing human resources, capital and technology, required for implementation of construction logistics solutions. Adoption of sharing economy models for SMEs impacts positively on environment and profitability for business and might even ensure company´s survival in difficult times (Soltysova & Modrak, 2020).

The adjoining research to this project has plotted the sharing economy model compass based on the composition of solutions for SMEs as depicted in figure 4.4. The shared economy model mapping suggests the use of a collaborative governance model wherein the resources are traded at a market value transaction.

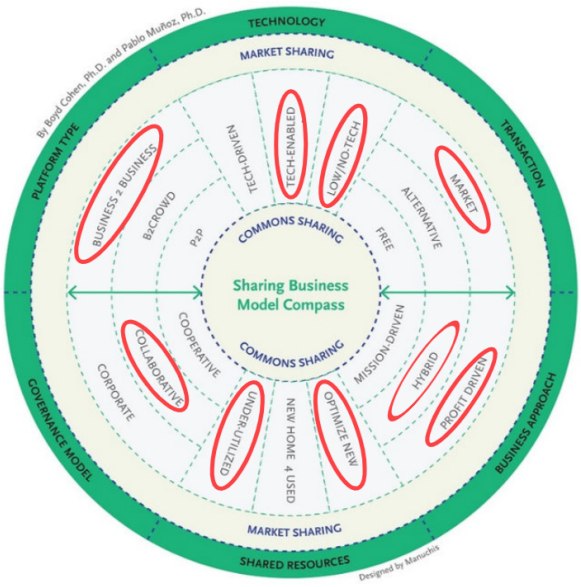


Figure 4.4: Shared Economy model mapping based on Molemaker (2020), Kloosterman (2020) and Hoogenboezem (2020)

4.4.2 Supply flows to construction site -integrated solution

As mentioned in section 3.1.3, there are 4 types of supply flows to a construction site in a traditional process. In addition to these flows, information flow in vertical and horizontal chain is a necessity in successful implementation of construction logistics solutions. In order to co-ordinate supply flows to the

site, information regarding type, quantity and time of delivery of product in accordance with Service Lease Agreements (SLAs) is important to organise the construction logistics solutions (van Merriënboer & Ludema, 2016). Information flow is bi-directional in terms of requirement to be sent to suppliers and transport organizers and incoming information for logistics to the site. Furthermore, to achieve Full Truck Load capacities in urgent delivery situations especially in finishing phase, inter-project delivery information sharing is a necessity. Also, due to multitude of subcontractors in the same project, a possibility of sourcing materials from the same supplier exists and hence, if co-ordination is facilitated via intra-project information sharing, it could lead to further reduced costs in the chain for all parties. Hence, Information flow could be regarded as one of the supply flows to the site in addition to the physical flows and is a necessity in case of implementation of construction logistics solutions.

4.4.3 Solutions Objective

The upcoming Green Deal 2025 and subsequent restrictions in 2030 in line with achieving the Paris Climate Agreement goals is targeting mobility sector to reduce emissions (Green Deal ZES, 2016). The City of Rotterdam has also planned certain restrictions to restrict entry of heavy goods vehicles in the inner city areas starting with the Rotterdam City Centre. A roadmap for 2025 indicates the vision of the city wherein most goods vehicles operate on cleaner fuels & have limited entries in the inner city areas to reduce emissions and nuisance for the residents (Green Deal ZES, 2016).

Eventually, transport operators would need to change their business model to adopt to these changes by revamping their fleet to emission-free vehicles and increase efficiency in transport movements by capacity-sharing. Particularly for SMEs in construction sector, a focus on capacity-sharing would better prepare them for these upcoming changes in legislation (de Vries & van Duin, 2021) and hence, the project focuses on such solutions to reduce construction-related transport movement in the inner-city areas and eventually lead to reduced emissions of CO2, NOx and PM10 to meet the objective of the Green Deal 2025 .

4.4.4 Solutions explored

Based on solutions requirements in section 4.1, a few solutions as suggested by interviewed participants was explored along with associated costs and benefits in table 4.3.

Table 4.3: Explored solutions with costs and benefits

Solutions	Costs	Benefits
Independent chain co-ordinator	• information sharing in the chain. • pre-planning of construction supply flows	• overhead costs.
White-labelled hubs	• Lower inventory requirement at site. • Lower inventory costs at supplier side. • Overall lower CO2 emissions in inner cities. • Lower kms travelled by transport. • Lower noise levels.	• increased lead time for loading and unloading. • limitations posed in case of heavy equipment.

Coupling and de-coupling trailers	• Overall lower CO2 emissions in inner cities.	• increased lead time for de-coupling process. • limitations posed in case of heavy equipment.
White-labelled trucks	• Better loading rate. • Overall lower CO2 emissions • Lower kms travelled.	• increased lead time for loading and unloading • lead time from supplier to site increases due to intermediate deliveries.
Carpooling/ shuttle buses for transport	• organisation costs if shuttle buses are opted • may require car-pooling apps if car-pooling with strangers to be enabled.	• Lower kms travelled. • Lower emissions.
Underutilized Asset- sharing via platform economy	• Transaction costs for platform economy solution used for B2B transaction.	• Added revenue by renting the equipment. • Lower number of equipment procured overall in geographical limits and hence reduced movements of vehicles.
Smart Returns - waste collection on return or sell to other parties	• No extra costs incurred.	• Reduced vehicle movements. • Reduced emissions.

4.4.5 Integrated supply flow solutions

A few integrated solution combinations are offered for the purpose of reducing game complexity and represent the appropriate solutions. As summarized in section 3.1, a construction site has 4 supply flows incoming to the site and their integration is required to carry out the allotted workplan. Due to increased collaboration in sharing solutions, another supply flow of Information coordinating site delivery schedules between different project or even intra-project is required and hence would be an addition to the 4 supply flows of personnel, material, equipment and waste.

For this purpose, an integrated approach from main stakeholders interviews is utilized to understand the desirability of the sector. The solutions that were common in builders, suppliers and transport providers interviews are:

- White-labelling of hubs and trucks
- policy regulations
- Increased chain collaboration

- Independent coordinator for information sharing in the chain
- Better planning to be encouraged via chain collaboration

These solutions short-listed above are derived from the list of solutions depicted in interviews conducted in adjoining research of this project and summarized in table 1.1. These solutions list is depicted in the figure 4.5 and short- listed solutions are denoted in black color in the figure.

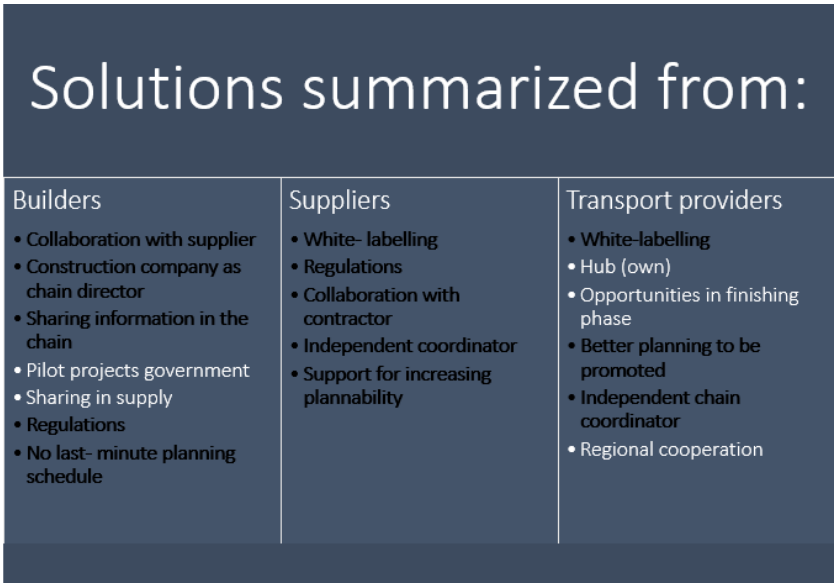


Figure 4.5: Solutions suggested by different stakeholders

Due to the absence of a particular project consideration, a baseline case is utilized in this project in accordance with the quantitative values gathered from the adjoining research to represent the costs & benefits of the solutions from the sector.

Table 4.4: Sharing solutions to be included in the session

Solution Name	**Material**	**Equipment**	**People +Tools**	**Information**	**Waste**
White-label hub	White-label hub	Regional 3PL contact	e-bikes at hub	Logistics manager per project	Waste carried downstream from sites
Strict Window Timings	Transport collects goods from all suppliers at once	Regional 3PL contact	Carpooling with tools	Logistics manager per region	Waste carried downstream from sites
White-labelled truck	Coupling/ de-coupling of trailers	Regional 3PL contact	Carpooling with tools	Logistics manager per region	Waste carried downstream from sites
Platform economy solution	White-label hub from DHL or other sectors	Via platform economy Werflink	Carpooling with tools	Logistics manager per region	Waste carried downstream from sites

The table 4.4 denotes the solutions to be used for this session targeted for finishing phase of the construction as summarized in section 3.1. These solutions are restricted to capacity-sharing given the low innovation practices in the sector, however, more efficient sharing solutions as well as more avenues of sharing were also explored from other sectors and will be represented as passive solutions. The costs

and benefits of the passive solutions are currently not included in this project scope and could be utilized as a discussion point for encouraging participants to explore creative practices of sharing in the session.

4.4.6 Costs & Benefits for solutions

The construction sector poses the challenge of unique nature of each project and hence its operations & related costs & benefits would be different (Koskela, 1992). The literature that presented costs & benefits calculations such as van Merriënboer and Ludema (2016) & Janné and Fredriksson (2019) for construction logistics solutions has been focused mainly on calculations for hub solutions employed for a specific project. These calculations incorporated data from Transport Management Systems (TMS) & Warehouse Management System (WMS) to estimate the right levels of KPIs measurement to determine the impact of these solutions.

In order to determine raw data for calculation of costs & benefits for this project, the adjoining research employed three student groups to conduct surveys for quantitative data collection on current business operations of the industry players namely construction builders, suppliers & transport providers. The survey received 13 responses from builders, 3 responses from suppliers & 13 responses from the transport providers. Given the low responses from the survey, the reliability of the data is indicative. A pre-check from industry experts before the session could be performed to verify the reliability of data used for the project. Moreover, the low responses from the survey could also be indicative of the reluctance of data sharing in the sector specifically for suppliers.

In absence of a particular construction project to analyse the data, this project employs a baseline case with raw data derived from the quantitative survey & literature specifics to present the realistic business case for the sector.

The baseline case depicted in figure 4.6 utilizes the the following case story & metrics for the calculations summarized in the session platform and manual:

A construction project in the finishing phase requires supply flows from 2 suppliers, 3 subcontractors, equipment for handling goods, waste collection from site & information flow in case of collaborative solutions.
The construction site has 5 supply flows coming to the site:

1. Material: Palletized goods need to be collected from 2 suppliers located in the same industrial park (3 km) on tractor-trailers (max. Euro-pallet capacity: 33).
2. Human Resources: 3 subcontractors need to come to the site and the reference distance point is taken as P+R (Park+ Ride) which is located about 6 km from the site.
3. Equipment: Equipment is hired from a transport provider situated 4 km away from the site.
4. Waste collection dumper: Construction site has accumulated waste from the activities. The waste needs to be handled. In Business-as -usual situation, specialised waste collection dumper is employed.
5. Information: This represents the information flow coordinated via an independent party appointed via the builder for the project or the municipality for the region.

Fang and Ng (2011) utilized the Activity-based costing approach to calculate construction logistics costs for the precast flow to site. The cost elements included in the calculation were inventory cost, transportation cost, site storage cost & procurement costs. Furthermore, in order to determine the

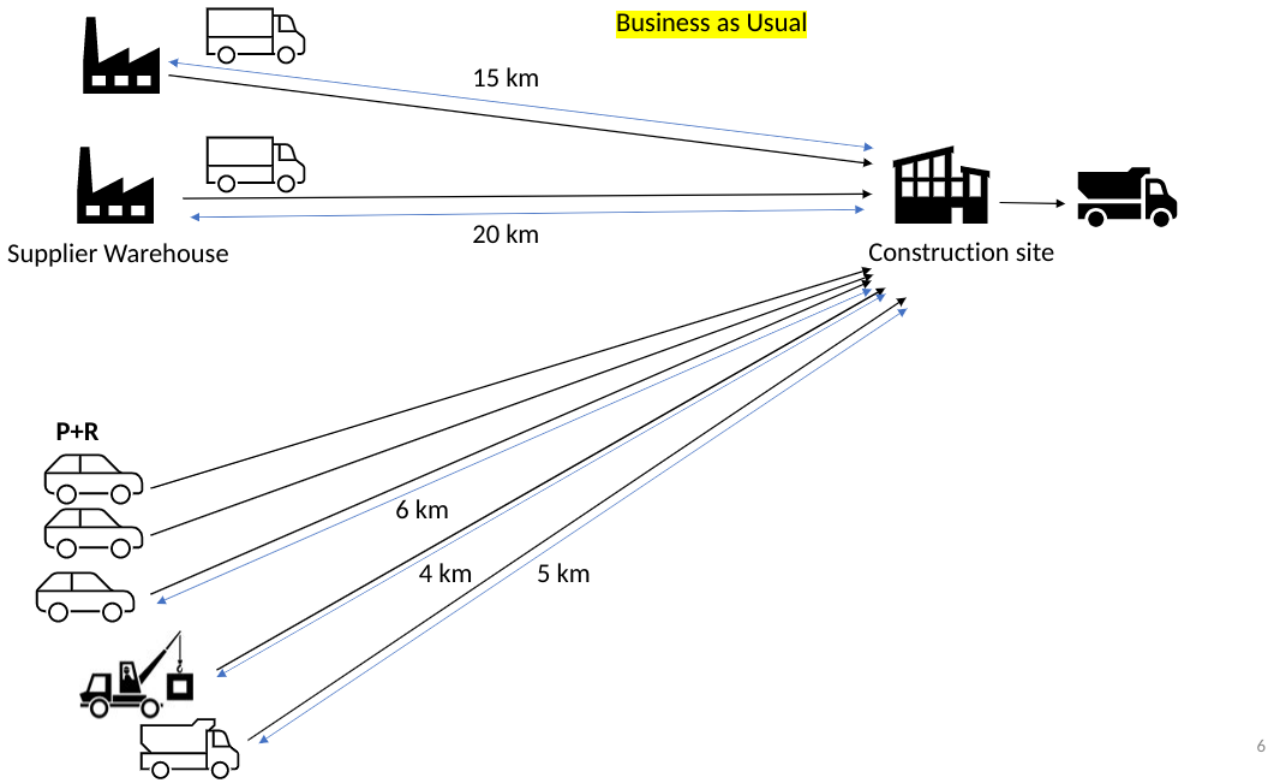


Figure 4.6: Baseline case

right cost elements, the identification of applicable cost drivers for each activity in the construction flow is necessary (Janne & Rudberg, 2017). Following the activity based costing approach for the case, very detailed cost drivers such as time for registering the goods at site or a intermediate storage are hard to determine. Hence, the activities accounted in the cost analysis for this project include handling costs , storage costs & transportation costs from collecting the material to delivery at site. Also, emissions calculations are performed to calculate the environmental impact of these solutions.

The costs & benefits data considered for the project is represented in ¨CBA 1¨ tab of the interactive platform. The activity-based costing could be referred in the ¨ Activity based calculation¨ tab of the interactive platform.

Table 4.5: Activity-based costing parameters

Activities	Parameters	Representation
At Supplier 1	Load material on truck at Outbound	L1
	Storage costs at Supplier warehouse	S1
At Supplier 2	Load material on truck at Outbound	L2
	Storage costs at Supplier warehouse	S2
Supplier 1- >Consolidation Point (CP)/ Construction site (CS)	Cost incurred for driving from supplier to CP/CS	D1
	Cost charged for transport	T1
	No. of trips	N1
	CO2 Emissions	EC1
	NOx emissions	EN1
	PM10 emissions	EP1

Supplier 1->Supplier 2	Cost incurred for driving between suppliers	DSH
	Cost charged for transport	TSH
Supplier 2 ->Consolidation Point (CP)/ Construction site (CS)	Cost incurred for driving from supplier to CP/CS	D2
	Cost charged for transport	T2
	No. of trips	N2
	CO2 Emissions	EC2
	NOx emissions	EN2
	PM10 emissions	EP2
At Consolidation point (CP)	Unloading material at CP	UCP
	Storage costs at CP	SCP
	Loading costs at CP	LCP
	Waiting time at CP	WCP
Consolidation point (CP)-> Construction site (CS)	Costs incurred for driving from CP to CS	DCP
	Cost charged for transport	TCP
	No. of trips	NCP
	CO2 Emissions	ECC
	NOx emissions	ENC
	PM10 emissions	EPC
At Construction site (CS)	Waiting time at CS	WCS
	Unloading time at CS	UCS
Personnel Transport	CO2 Emissions	PEC
	NOx emissions	PEN
	PM10 emissions	PEP

The table 4.5 depicts the activities taken in account for calculations aligned for the baseline case. The transport costs and emissions are calculated per trip taken by the transport in terms of costs incurred and costs charged to the clients whereas the handling costs and waiting costs are calculated from time taken per terminal of the delivery. Furthermore, for costs of transport taken by subcontractors/personnel coming to the site do not directly impact the project costs and may only lay impact if these costs are either reimbursed or arranged by the builder. Thus, the only calculations included for personnel is the environmental impact due to car-pooling solution.

The calculations are performed for each actor per activity due to the collaborative nature of the session. These costs are charged incrementally to each actor in the chain such as transport costs incurred by transport provider are charged to the supplier that then includes it in the invoice of the material charges incurred to the builder. Thus, if there is a reduction in kilometres travelled or logistics costs by employing Just-in-time practices in the chain, all actors might encounter lower operational costs that is exclusive of organisational costs. The solutions are targeted to work on these parameters via capacity sharing & better information flow leading to positive impact on chain costs and a positive environmental impact as well.

Costs incurred for transport provider consists of costs incurred for driving to and from terminals as well as waiting times for unloading, loading and waiting in line to be attended. Among the parameters, for transport providers, these costs are:

Costs incurred by transport provider: (L1 + D1 + WCS + UCS)* N1 + (L2 + D2 + WCS + UCS)* N2 + DSH

In case of suppliers, the costs incurred involve storage costs and loading costs at outbound and costs

charged by the logistics provider for material delivery through the entire trip. Currently, the use of consolidation point facilities are assumed to be booked per project and are mostly added in organisation costs for builders. Hence, the suppliers are supposed to cover the trip costs except the consolidation point costs. Among the parameters, for the suppliers, the costs include:

Costs incurred by supplier: S1 + (L1 + D1 + WCS + UCS)* N1 + S2 + (L2 + D2 + WCS + UCS)* N2 + TSH
Costs incurred by supplier= Costs incurred by transport provider + profit margin for transport providers + storage costs at outbound

In the above equation, T1 and T2 are representative of costs charged by transport provider for the trip including fixed and variable costs incurred for transport and driver in addition to profit margins. Additionally, S1 and S2 are additional charges incurred by suppliers solely in the chain.

For builders, the costs incurred comprise of the invoice presented by the supplier for material costs and delivery charges. In this case, the material costs are set at 200 euros for purpose of session and are inclusive of inventory costs for the supplier. An additional profit margin of 5% is added on transport costs for suppliers to compensate for overhead charges and administrative charges. Among the costs parameters represented in table 4.5, the costs incurred by builders include:
Costs incurred by builder : ((L1 + D1 + WCS + UCS)* N1 + S2 + (L2 + D2 + WCS + UCS)* N2 + TSH)*profit margin of suppliers + Material costs
Costs incurred by builder= Costs incurrred by supplier (assuming material costs include the storage costs) * profit margin of suppliers

The rest parameters of consolidation point such as UCP, SCP, LCP, WCP and transport costs from CP to CS are considered to be part of costs of organisation of solution and would be charged to the particular party that organises the solution for the particular case. In addition to operational costs of organisation, fixed capital costs of organising the solutions are also involved in calculations for the session.

Next, these cost calculations and assumptions are presented per solution per actor in the chain. From the perspective of reducing costs and emissions in the chain, the main targets are reducing the overall kms travelled by the transport and reducing the number of vehicles engaged in delivery of supply flows to the site. Also, due to unavoidable uncertainities in this phase of the construction process, the number of trips made to the supplier represented by N1 and N2 in table 4.5 are quite important since consolidation point could contribute significantly in reducing the total number of kms covered for the trip as well as congestion and emissions.

4.4.6.1 Solution 1: Business-as-usual

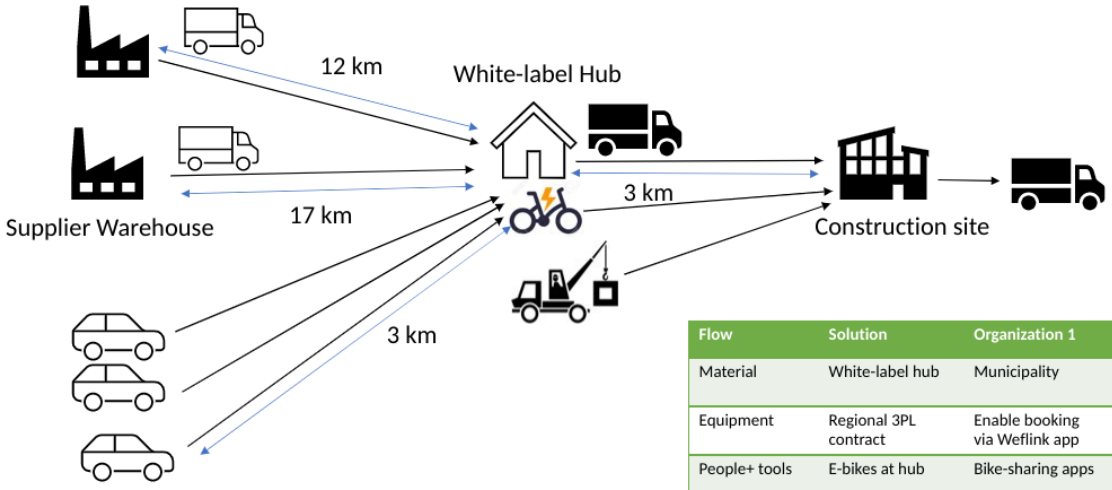
This solution refers to ¨Do Nothing¨ scenario. No innovations or change in working has been observed for this solution & hence no improvement in costs or emissions is observed from the chain. Each supplier employs their own transport provider that delivers to the construction site separately with non Full-truck Loads. The subcontractors along with their tools arrive in different vans to the construction site. Equipment arrives at the site as per requirement specified by the builder. Also, an empty waste collection dumper arrives at the site and carries waste to the waste management site. The figure 4.6 depicts the Business-as-usual solution.

4.4.6.2 Solution 2: White-label hub

The second solution proposed comprises of a white-label hub strategically located near the edge of the city by Municipality or arranged on a vacant site nearby site by either builder or the transport provider.

Trucks from supplier sites deposit material at the hub that are then delivered to the site Just-in -Time in a consolidated delivery. The subcontractors utilize e-bikes present at the hub in case the solution is arranged by the municipality else they carpool to the site. The equipment is parked at hub & arrive at the site as per project requirement. Also, the truck that delivers the material to the site caries the waste downstream to the waste collection site. An information coordinator is also assigned for the project to overlook the requirements are met for the projects. A micro-hub is also employed in the solution that works on the principle of Vendor-Managed Inventory & refills frequent required materials such as insulation, etc. ("TNO Onderzoek Bouwhubs MOVE PZH - eindrapportage_handout (1)", n.d.). The hub stores material by the suppliers and in event of uncertainty, the transport from hub would deliver the goods to the site as opposed to from the supplier. Thus, NCP would replace N1 and N2 in the calculations reducing the number of kms travelled and lesser number of transport. However, the consolidation might produce a delay in addition with handling time and administrative time at the hub.

The figure 4.7 depicts the parameters considered for costs and benefits calculations for this solution.

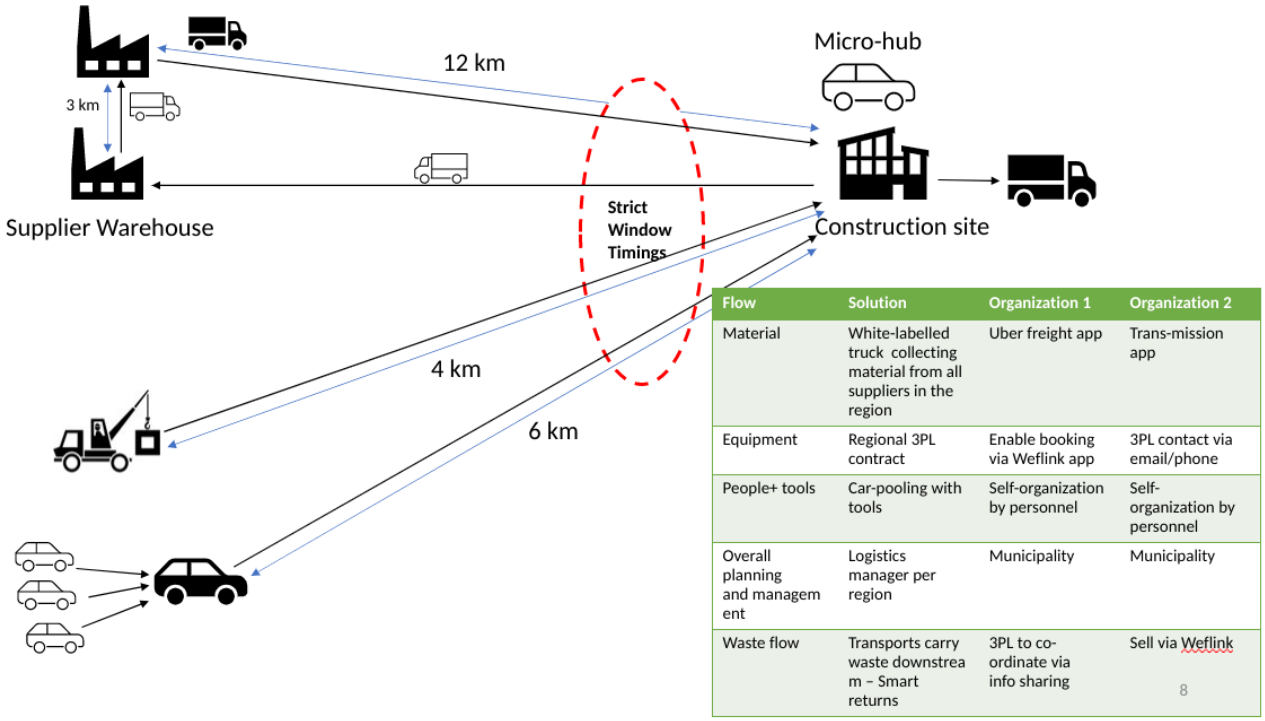


Flow	Solution	Organization 1	Organization 2
Material	White-label hub	Municipality	3PL at vacant land near hub
Equipment	Regional 3PL contract	Enable booking via Weflink app	3PL contact via email/phone
People+ tools	E-bikes at hub	Bike-sharing apps	
Overall planning and management	Logistics manager per project	Hired via StaffU	Additional responsibility to planner – no extra costs incurred.
Waste flow	Transports carry waste downstream – Smart returns	3PL to co-ordinate via info sharing	Sell via Weflink

Figure 4.7: White-label hub solution

4.4.6.3 Solution 3: Strict Window Timings

Strict window timings is a policy innovation utilized by municipalities to restrict entry of vehicles during traffic rush hours. A single transport collects consolidated deliveries from suppliers & needs to make only one trip due to better planning enforced by the solution. Thus, the N1 and N2 are reduced to 1 with additional trip between suppliers. The subcontractors arrive at the site via car- pooling. The equipment is rented from the specialist firms & waste is collected downstream from site. Solution could be digital technologies like Uberfreight or Transmission app. Also for personnel, car-pooling is an option or taking public transport. The figure 4.8 depicts the parameters considered for costs and benefits calculations for this solution.



Flow	Solution	Organization 1	Organization 2
Material	White-labelled truck collecting material from all suppliers in the region	Uber freight app	Trans-mission app
Equipment	Regional 3PL contract	Enable booking via Weflink app	3PL contact via email/phone
People+ tools	Car-pooling with tools	Self-organization by personnel	Self-organization by personnel
Overall planning and managem ent	Logistics manager per region	Municipality	Municipality
Waste flow	Transports carry waste downstrea m – Smart returns	3PL to co-ordinate via info sharing	Sell via Weflink

8

Figure 4.8: Strict Window Timings solution

4.4.6.4 Solution 4: White-label truck

Two non full-truck deliveries are consolidated by decoupling and coupling of trailers onto a single truck & might require more than one trip due to uncertainties in the sector. Hence, the N1 and N2 might be similar to the ¨Business as usual¨ situation, however, the bundling of goods would reduce the number of vehicles and also a few kilometres travelled by 2 non-FTL trucks .The subcontractors arrive at the site via carpooling. The equipment is rented from the specialist firms & waste is collected downstream from site. The figure 4.9 depicts the parameters considered for costs and benefits calculations for this solution.

4.4.6.5 Solution 5: Platform economy solution

The platform economy solution enables use of digital platforms offering shard warehousing space for the storage of material , etc. This solution is similar to the while label hub solution but use of digital platforms that may be outside the sector could act as a threat to construction sector solutions. However, the hubs may be located farther away from the construction site due to access for other sectors as well. Hence, this solution could be viewed as a threat to the construction sector if efficient practices are not adopted maybe another players could offer better services or solutions to clients at lower rates. The figure 4.10 depicts the parameters considered for costs and benefits calculations for this solution.
Best practices for efficient logistics from other sectors and organisations in terms of sharing production resources are summarized below:

4.4.6.6 Solution 6 (passive): Kitting services- IKEA

The materials from hub required for the work on a site could be packed in one kit similar to IKEA services and delivered to the site (Moussaoui, Lafhaj, Leite, Fléchard, & Linéatte, 2021). This could be combined with the Just-in-time (JIT) concept wherein the materials are delivered at the site to be used immediately no necessity of storage (Moussaoui et al., 2021).

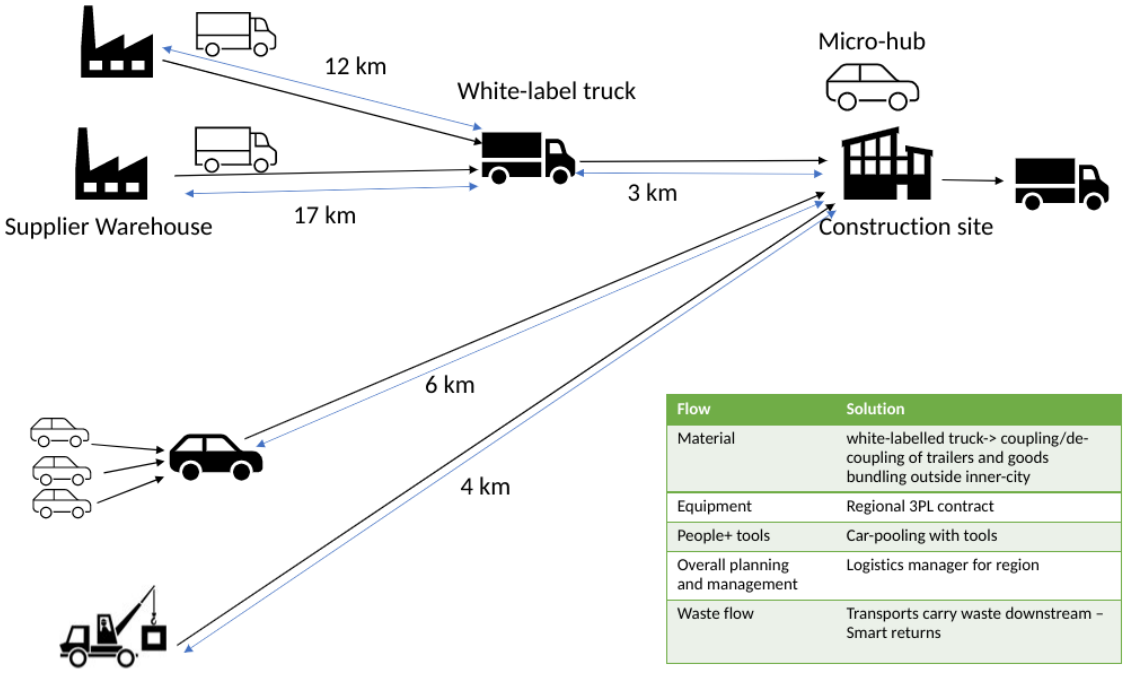


Figure 4.9: White-label truck

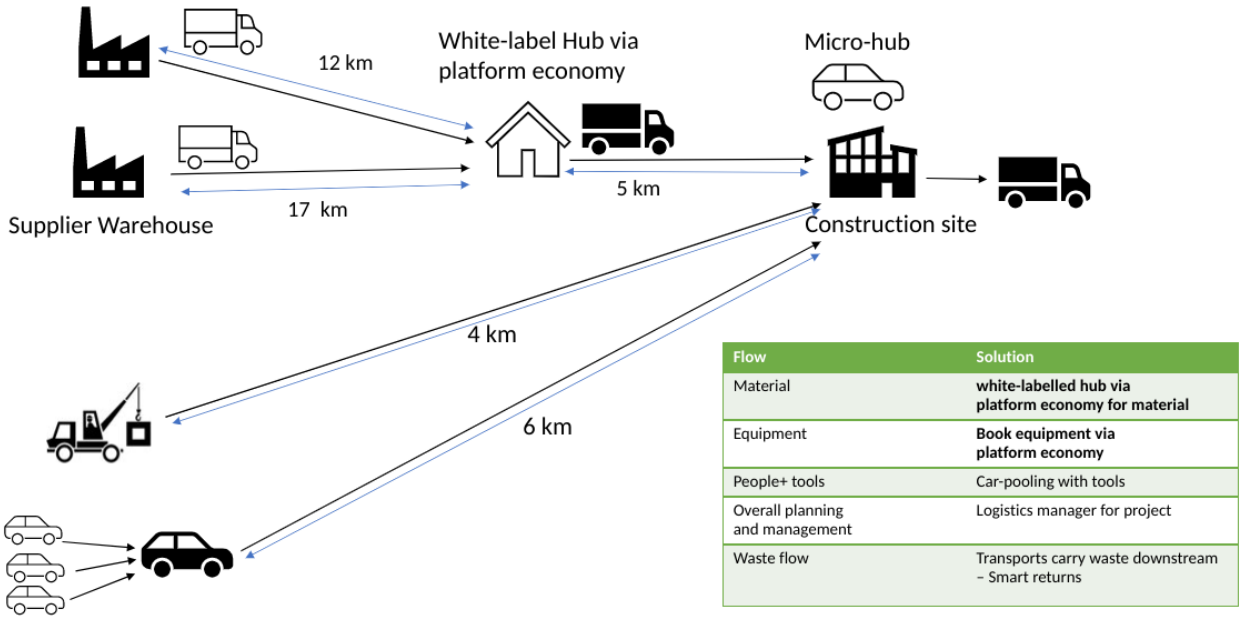


Figure 4.10: Platform economy solution

4.4.6.7 Solution 7 (passive): Collaborative bulk raw material purchasing: ZARA

The construction sector has seen sharp increase in building materials prices such as timber, wood, plastic and cement in 2021 and have been at an all time high in 30 years (*Building costs go through the roof adding pressure on contractors' margins | Article | ING Think*, n.d.). These prices are expected to go up in coming months and lead to decreased margins for contractors in the sector (*Building costs go through the roof adding pressure on contractors' margins | Article | ING Think*, n.d.).

The sharing example from ZARA could minimize this impact. ZARA buys most of its fabric in bulk and then customizes it according to the design demanded by the fashion industry. The material suppliers´ could buy these raw materials in bulk subsidising the costs and later customizing it as per customer´s requirements (Ludema & Vries, 2015).

4.5 Conclusion of Session Design Elements

The chapter summarizes the various design elements for designing a engaging session for depicting the business case calculations as per requirement from the stakeholders. The section 4.1 established the theoretical requirements of an session design for effective learning such as flow theory, scaffolding mechanism for de-briefing and session type with a set-up of a collaborative gameplay. Furthermore, a stakeholder analysis was conducted in section 4.2 to choose the type of stakeholders to be represented in the session and stakeholders with high power and high interest in the influencing the adoption of collaborative solutions were considered as necessary participants and other stakeholders were decided to be represented by the parameters impact in the play-session. In order to understand the impact of collaborative practices in the chain, qualitative tensions and trade-offs for parties are also explored in section 4.3 via interview analysis from adjoining research to be represented as flexibility parameters in the session. The quantitative trade-offs and impacts are depicted via make-believe case due to absence of a particular case project in consideration. The section 4.4 determines the operations of different solutions via diagrammatic representation taking in consideration the number of kms, handling time and waiting time data for costs and benefits calculations. This chapter concludes the design elements that needs to be operationalised and incorporated in the overall session.

Chapter 5

Practical Session Design

This chapter focuses on the collaborative session design process based on the requirements derived in section 4.1. The design follows an iterative process of refining as per Harteveld (2011). The final prototype was play-tested with industry experts to evaluate the effectiveness of the session and eventually increase the quality of the game to make it appropriate for the practitioners.

5.1 Discussion

Based on the requirements of the session, the mechanisms that need to work for the session are:

- multiple players could collaboratively access the platform.
- Overall costs for solutions including Operational costs & organisational costs to be presented.
- Qualitative trade-offs to be presented
- Gain-share or cost-share mechanisms
- goals for players

5.1.1 Choice of platform

In terms of a multi-player collaborative platform solution, multiple game platforms & collaborative tools were explored of which the game platform Construct & Google sheets seemed suitable for the solution. Given the low-tech nature of the session & capabilities of the designer since main focus would be on the graphical feedback, Google sheets would be a suitable option in this case. Also, a familiar platform like Excel might be easy to work for the participants.

5.1.2 Elements of the in-play session

The required interplay mechanisms were laid out in terms of steps to be discussed in the session. Starting with solution exploration & trade-offs inclusive of productivity, cost reduction, emission reduction & flexibility change for players, the first step would include these factors to let players collaboratively choose a solution. The second step would be to organize these solutions & the costs behind them. Based on the collaborative agreement by the players, the total costs for each player could be determined as per the use case in the session. Next, to provide an incentive to keep working together, the saturation of costs on a single player need to be reduced as the collaborative solutions lead to synergy for all parties in the chain. Hence, a cost-share mechanism would be in interplay at last simulating a contract signing clause for the project.

5.1.3 Parameters in the play-session

The interviews from the industry practitioners in the adjoining research revealed a need for a business case for the solutions proposed for the sector. Though the industry is aware of the existing solutions but a clear business case with gains and pains for the new ways of working would create openness towards these solutions and hence increase awareness in the chain. In addition to the quantitative parameters of costs, qualitative parameters such as productivity & flexibility were also included since these are important criteria for adoption of solutions in the chain by SMEs as depicted. These parameters were depicted in the platform against each solution choice & its organisation agreed by the team collaboratively. The parameters definitions are provided below:

- **Costs:** The costs include transport costs, storage costs, waiting time and handling costs for the material from the suppliers.
- **Emissions:** This parameter represents cumulative emissions of CO2, NOx and PM10 emissions.
- **Time:** This parameter represents the lead time for activities in the construction logistics such as material loading time, material unloading time, waiting time at hub, waiting time at construction site due to restricted/open space.
- **Productivity:** Productivity at construction sites stands for acceleration in production time due to improved coordination in the construction activities and good internal logistics enabling availability of all flows at the site at the same time. Productivity is viewed as a profit field for the builders as it leads to less delay in construction project overall and low spend of construction costs leading to better margins as summarized in sections 1.1 and 4.3.
- **Flexibility:** This field could imply different meanings for different roles in the game as depicted in the table B.1.

Table 5.1: Flexibility parameter criteria

Role	**Implication of Flexibility field**
Builder	Builders are currently ordering the material and supplies on adhoc basis following the today for tomorrow model, but if a solution needs to be implemented successfully, a better plannability is required.
Supplier	Suppliers are specialists in their particular products and are apprehensive regarding the data-sharing with their competitors, but if a solution is required, they need to be ready to share this data amongst their competitors.
Transport Provider	Transport providers may need to share their gains with other competitors and might even face restricted movement such as regional movement in a few solutions.

5.1.4 Flow of the session

The above steps need to be adjusted to the flow of the session to keep the participants engaged throughout. According to the flow theory, flow is achieved when there is an optimal balance between the challenges presented & skills of the participants (Biasutti, 2011). Moreover, in learning, the use of digital games has proved effective to engage learners (Schmidt, 2010). Though the impact of flow in learning was performed mainly in children, there is little evidence on its impact on people of different ages (Schmidt, 2010). Hence, in order to keep the participants engaged in the session, an increasing level of challenges needs to be induced in the session in addition to gaming elements.

A flow in the session was targeted to be achieved by modifying the goal assessment part of the serious games. The participants would be provided with competitive goals in teams to increase engagement & explore aggressive options provided in the platform. A collaborative game session was chosen to be the

best representation in this situation given its criteria of collaborative win by the team while balancing overall team goal & individual utility (Zagal et al., 2016). Hence, the idea of two collaborative teams each representing at least 1 member role of the construction project was decided to be incorporated for the session. Additionally, the goals for the teams increases with each session. So, in the first session, the goal is kept familiar to the current operations i.e. to save most costs by the players. An increased difficulty was added in the subsequent session where participants had to save the most costs & emissions for the project operations. This takes in account the upcoming Green Deal implications & awareness towards environmental aspect as well.

The iterative design for the session tries to include the aforementioned aspects in inspiration from other sources or games.

5.1.5 Practical Design Elements

Existing games & theories were explored from the construction logistics sector & gaming sector to be represented in the platfor and summarized in table 5.2.

Table 5.2: Existing sessions for collaborative resources or games

Game	**How it works?**	**Actors represented**	**Source**
Construction logistics game by MIMIC society	Municipality passes policy to be followed in the session; Builders bid on solutions and implement on a board-> effects could be seen; congestion caused; emissions.	Municipality & Builders	Source: Bergström, Billger, Fredriksson, and Janné (2020)¨The MIMIC construction logistics game: facilitating group discussion and understanding of construction logistics through gameplay¨
Collaboration for forest resources	Co-operative game for route optimisation and encourage co-operation for regional deliveries based on location. Costs and benefits provided for each scenario in first session and only locations of each player provided in second session: costs and benefits to be discussed in debriefing.	Companies supplying wood located in different regions of Netherlands.	Source: D'Amours and Rönnqvist (2010)¨An Educational Game in Collaborative Logistics¨
Reigns	Choice scenarios presented in Yes/ No form and player decisions will lead to the solution. Multiple forms of assessment beyond costs such as lives saved; religious decisions ,etc.	Single player game/ choice game.	Source: DevolverDigital(2016) ¨Reigns: Trailer Launch (Youtube)¨

Bouwlogistiek @work game	Developed by TNO; represents system interplays between site storage and construction plan and the player needs to plan deliveries based on uncertainties in the sector such as supplier delayed shipment, delivery truck had a breakdown,etc. Allows for role change with the chain director to allow information sharing in the game.	project planner & chain director	Source: BouwendNederland(2020) ¨Bouwlogistiek@Work: game for collaboration in construction logistics¨

The session design is inspired by the depiction of theoretical in the practical game examples presented in table 5.2. The game by Bergström et al. (2020) depicts the governance of policies in the game guiding the goal of the overall play session. The forest resources game by D'Amours and Rönnqvist (2010) uses the scaffolding mechanism of learner profiling, feedback and de-briefing in addition to incremental challenge per mini-session as per flow theory. This concept could be utilized in the session design for this project as well. The reigns game by DevolverDigital (2016) uses multi-criteria decision-making for trade-offs per decision made by the players by displaying it via different symbols altogether. The various parameters addressed in the section 5.1 could be depicted in a similar way in the tool. Lastly, the game Bouwlogistiek@work by BouwendNederland(2020) represents the various uncertainties and their related system interoperabiltiies for construction logistics. A similar depiction is used in the play-session design for negotiation and sharing parameters .

5.1.6 First prototype of Interactive session

The first prototype of the session included three mini-sessions followed by de-briefing sessions in accordance with the scaffolding principle. The first session was to be used as a try-out session to ensure the understandability of the interplay for the players in the de-briefing with queries related to the game mechanisms. In the intention of motivating the players to approach more aggressive solutions in the next mini-session, gaming elements as according to Baalsrud Hauge et al. (2014) were added to make this experiential learning more engaging. Two teams were introduced to make it more competitive for the players with in-game assessment like scoring mechanisms to increase engagement & assess players' learnings. Also, surprise game elements like assignment of non-collaborative player were introduced in the play-session that would fetch extra points for collaboration.

Regarding the platform development, the attempt was to reduce the complexity of the play session while allowing minimum & simpler inputs from players. The platform capabilities play a major role in determining these factors. The graphical output function from the Google Sheets interface was utilized in this case for allowing players to assess the impact of different solutions. In addition, trade-offs were expressed as percentages & symbols to indicate the impact of solutions on the players. Also, the gain-sharing mechanisms for material costs & transport costs were not linked to better plannability & were solely based on verbal agreement from the builder in the session.

The interactability of the platform was complex for players in terms of selecting the solutions wherein they were advised to indicate ¨YES¨/¨NO¨ against each solution. Also, the organisation options for all solutions were displayed in a pivot table & with many options to choose from at once that was not shortlisted according to the solution chosen on the previous tab. Many irrelevant options at once could have confused the participants regarding the playability of the game.

The low interactability of the platform was anticipated to be more complex in this iteration & was targeted to be improved in the next iteration.

5.1.7 Second prototype of interactive session

The second iteration of the platform focused on allowing maximum output to players with lower inputs & to provide stricter system interplays in the platform itself. This prototype was modified with better interactable options such as a checkbox for the solutions instead of text. Also, organisation options were sorted in tables such that ¨FILTER¨ option in Excel could be applied to only see the relevant organisation options for the solutions. This option was chosen since it is a familiar option in Excel & would not require less operation from the players. A graphical representation of costs and benefits was also added on the ¨Solution Organisation tab" so the total costs could be compared with the Business-as-Usual solution so as to reduce the frequent need of switching between tabs.

Furthermore, for the gain-sharing mechanisms, a story line of contract signing was constructed with 2 clauses for cost-sharing to be discussed for this purpose. The first clause concerned cost of organisation share which could be indicated in percentages per stakeholder. A graphical representation & was also added to provide insight to the participants of distinction in old cost-share and new cost-share with the cost of organisation share clause. The second clause considered the system interplay of planning ahead by the builder and would result in reduced storage cost for supplier(s) & bundling certainties at the transport provider front. As opposed to first iteration where it was left mostly on verbal agreement, in this iteration if only the clause is agreed to by ticking the checkbox by the builder, the sharing mechanisms would be activated for stakeholders to offer concession on material price or transport cost for the builders eventually bringing down the operational costs.

Also, for the creative solutions to be given in the last mini-session, a few sharing solutions from other sectors would be introduced to stimulate the discussion & then allow players to explore solutions they came across during the previous sessions or inspired from given solutions.

5.2 Detailed Design

The overall session is targeted to be held online in the current circumstances of pandemic and to be scheduled for approximately an hour. Though the game does have the capability to be held in a physical location with 2 separate rooms.

5.2.1 Overall session

The overall session and agenda is depicted in figure 5.1 and 5.2. The various mini-sessions are based on the scaffolding principle of gameplay.
The agenda depicted in figure A.2 represents the various mini-sessions and time-allotted to each session and activitiy that takes place in the session.

Given the participants could belong to varied companies and may have less knowledge regarding the other participants, an round-tale introduction will be the start of the session with time-allotted as 5 minutes. Next, the facilitator presents a pre-session brief consisting of elements as described in section 5.2.2. As depicted in figure A.1, the session is divided into 3 mini-sessions with different purpose and learning activities. The first mini-session (Session 1) is utilized as a tutorial session for the players and is allotted around 7 minutess as a test- time to allow the players to navigate through the platform. However, this time could be adjusted in the gameplay due to the perceived complexity of the platform by the participants. A detailed session is described in section 5.2.3.1. This session is followed by a de-briefing session to ensure the understandability of the platform mechanisms with targeted questions as depicted in section 5.2.3.2. This session is allotted the time-limit of 5 minutes, however an extension of time limit is recommended to the facilitator in case the participants require better understanding of the platform. The session 2 is the actual play- session with added challenges

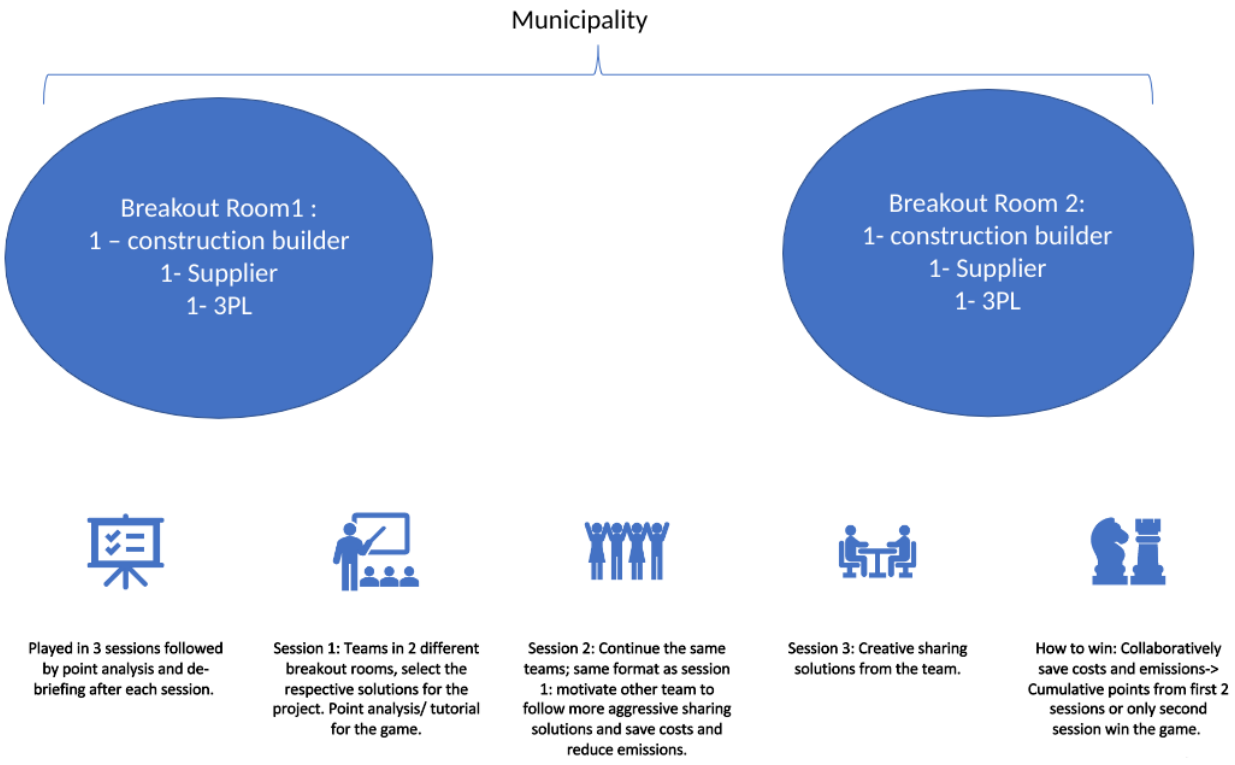


Figure 5.1: Overall session

Figure 5.2: Session agenda

from session 1 and point-bearing activities incorporated. Since, it is perceived that the players are now adapted to the platform mechanisms, it would be easier for them to navigate through the platform and find suitable combinations during this session. However, analysing the different options is the task of the team in this session. The platform does present multitude of solutions but many options might overboard the participants and hence, a time-limit is set at 10 minutes to allow some solution explorations and choose among these solutions. The de-briefing session 2 would be targeted to analyse the practical analysis and trade-offs made for the solutions, thus, establishing different factors and learning for the sector that might work for a realistic project. This de-briefing session would also allow for gain-sharing explanation. Furthermore, the next collaborative session would be utilized for conducting the gain-share exercise followed by creative solutions discussion and feedback on the game. Due to multiple activities integrated in this section, a prolonged timing is allotted at 15 minutes.
The flow of the session poses incremental challenges to keep the players engaged throughout the session.

5.2.2 Pre-session Brief

The pre-session brief is a powerpoint presentation depicting the idea towards the gameplay in the session and overall session brief to introduce the session to the participants. The elements in the pre-session breif include:

- Agenda of the session
- Problem of the sector
- Research basis
- Session interplay and brief of parameters
- Storyline & goal of the play sessions

The session manual added in appendix A that depicts step-by-step procedure for navigating through the platform is also shared in this session.

5.2.3 Session

The overall session is divided into 3 mini-sessions with increased level of challenges on the principles of flow theory. Session 1: The first mini-session is used as a tutorial & provides chance for the players to have a mock session & understand the interplay that the platform aims to provides and contemplate information depicted via trade-offs. This session aims to keep the difficulty level to minimum by introducing a familiar situation to players wherein their aim is to save maximum costs as a team.
At the start of the session, the participants are divided into 2 teams of 3 players with roles of builder, supplier & transport provider allotted to each of them. The builder would act as the captain for each team and would be provided with the EDIT access to the platform. In addition, the captain would have the below responsibilities:

- The builder would be the only player in team possessing EDITING rights to the platform and hence would be able to enter choices to the platform and obtain results. The builder would share the screen in the team room and would be responsible for choice entry in the platform.
- The builder is responsible for briefing the facilitator of the course of discussion in the play session to the session facilitator. The other players could add-on to the discussion if they wish to.

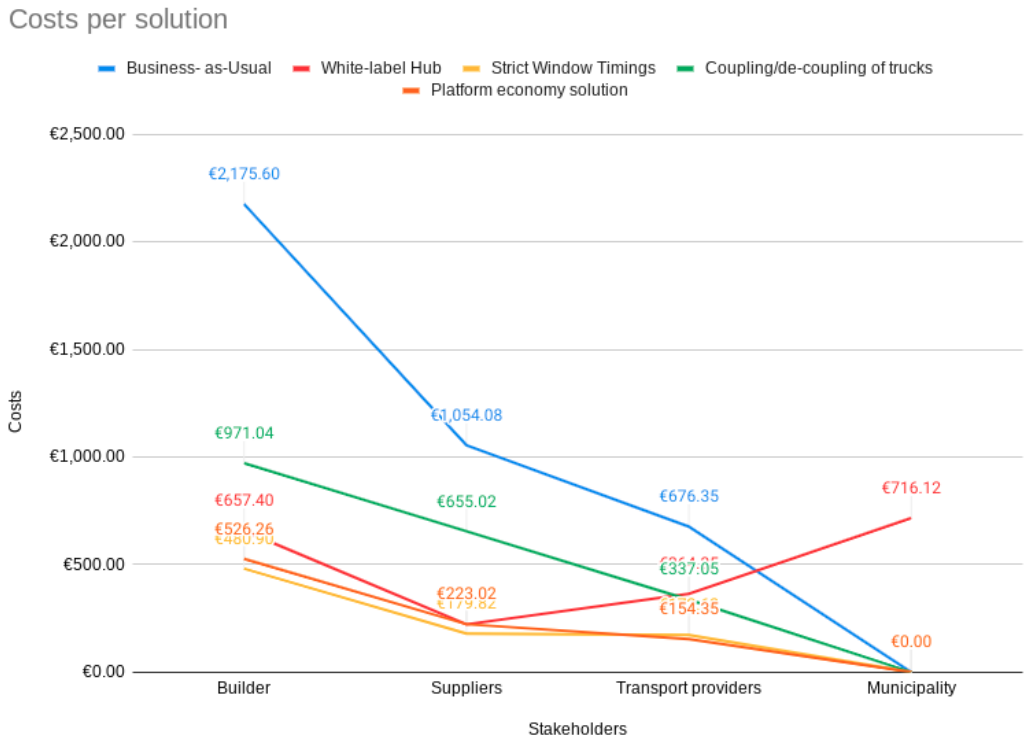


Figure 5.3: Costs per solution per actor

5.2.3.1 Play session 1 design:

The first play session was targeted to provide the players with awareness of the solutions considered in the session & the impact of these solutions . The Play-session 1 Tab displays the operational costs per solution proposed in the session as depicted in figure 5.3. This would act as an input for the choice of solutions presented in the sheet below: Furthermore, the sheet presents the construction logistics solutions with integrated supply flows to the site & its related trade-offs for the participants. This presents the participants with detailed working of each solution & would facilitate discussion upon sharing aspects in the solutions presented.

For instance, if the team chooses to explore ¨White-label hub¨ solution as depicted in figure 5.4, the captain needs to check the solution they want to explore and the respective parameters would be displayed for the solution as depicted in figure 5.5. The parameters determine the trade-offs presented for the solution. When a sharing solution is chosen, the operational costs are reduced in the chain. These costs are representative of the project costs as depicted in 4.4. However, an increased timing for overall process might increase due to increased operations time due to consolidation administrative added times in addition to the bundling opportunities dependent on other project activities as well. Though, an increased productivity is expected from the solutions and is currently set at 32 % from the TNO research due to the data limitations for other solutions. This metric acts as cost opportunity for builders and lowers he project costs by reducing chances of project workplan delays. A lowered flexibility parameter serves as a negative value in different manners by different stakeholders involved as summarised in table B.1.

Once the solution to go for is chosen, the next step is to organise the solution. The different supply flows to the site are represented in the TAB: Solution Organisation Cost for play session 1. For differentiation for each flow, a different colour is used. The captain of each team needs to indicate Y against each organisation flow that the team collaboratively chooses to go for in the session as depicted

Solution Choice:

Solution Number	Solution Name		Material	Equipment	Personnel	Waste	Information
1	Business-as-Usual	☐	Separate trucks from separate suppliers	Equipment from 3PL contact - could be non-regional	Personnel coming in separate cars with tools	Special dump trucks to be deployed	No logistics manager
2	White-label Hub	☑	White-label HUB	Regional 3PL contact	e-bikes @HUB	Trucks carry waste downstream - Smart Returns	Logistics manager per project
3	Strict Window Timings	☐	White-labelled truck collecting material from all suppliers in the region	Regional 3PL contact	Carpooling with tools	Trucks carry waste downstream - Smart Returns	Logistics manager per region
4	Coupling/De-coupling of trailer	☐	Bundling of goods	Regional 3PL contact	Carpooling with tools	Trucks carry waste downstream - Smart Returns	Logistics manager per region
5	Platform economy solution	☐	HUB via platform economy	Share equipment via app	Carpooling with tools	Trucks carry waste downstream - Smart Returns	Logistics manager per project

Figure 5.4: Solution Exploration in the session

Parameters:

Costs	70.00%	▼
Time		▲
Productivity	32%	▲
Flexibility	Low	▼

Figure 5.5: Parameters against the chosen solution

in figure 5.6. The organisation table depicts the concerned stakeholder for each organisation option that would bear the corresponding costs. This would require a collaborative decision for the chain players & would depict a trade-off in personal utility vs the team´s goal. Furthermore, an added organisation cost for the stakeholder is represented in an adjacent graph that can be compared with the Business-as-usual solution as well as depicted in figure 5.7. The target for teams is to determine an optimum collaborative solution given these parameters as inputs.

Select Y/N for the Supply flow organisation	Flow	Solution Description	Actor	Solution Name	Costs of solution organisation
Y	Material	Municipality organises Hub and charges builder on pay-per-use model	Builder	White-label hub	€133.94
	Material	Municipality provides incentives for organizing hub solution (currently set at 40%)	Municipality	White-label hub	€53.58
	Material	3PL organises hub solution on vacant land nearby site	Transport providers	White-label hub	€133.94
	Equipment	Regional 3PL contact booking via FLOW 2 App	Transport providers	White-label hub	€10.00
Y	Equipment	3PL contact via email/phone	Transport providers	White-label hub	€82.11
	Personnel	E-bikes @HUB if Municipality organises the solution	Municipality	White-label hub	€59.25
Y	Personnel	Re-imburse 80% of bike use costs to subcontractors in case municipality does not organise the hub solution	Builder	White-label hub	€47.40
	Personnel	Car-pooling with tools if 3PL organises the solution	Self-organisation by subcontractor	White-label hub	€0.00
Y	Waste	Trucks carry waste downstream-Smart returns	Transport providers	White-label hub	€200.00
Y	Information Flow	Regional Logistics Manager	Municipality	White-label hub	€656.87

Figure 5.6: Solution organisation interactive table

Due to the addition of costs from organising the solution, the total costs for the chain has changed and now the cost reduction has reduced by 2% depicted in the figure 5.8.

This parameter is representative of the increased costs in the chain due to the added 2% of costs added when the team tries to organize the solution. This step is added to isolate the impact and options when the project team discusses the organising a preferable solution since this was one of the blind-side for the challenges faced by the SMEs.

This play-session was presented as a tutorial session & would not be assessed for this interplay.

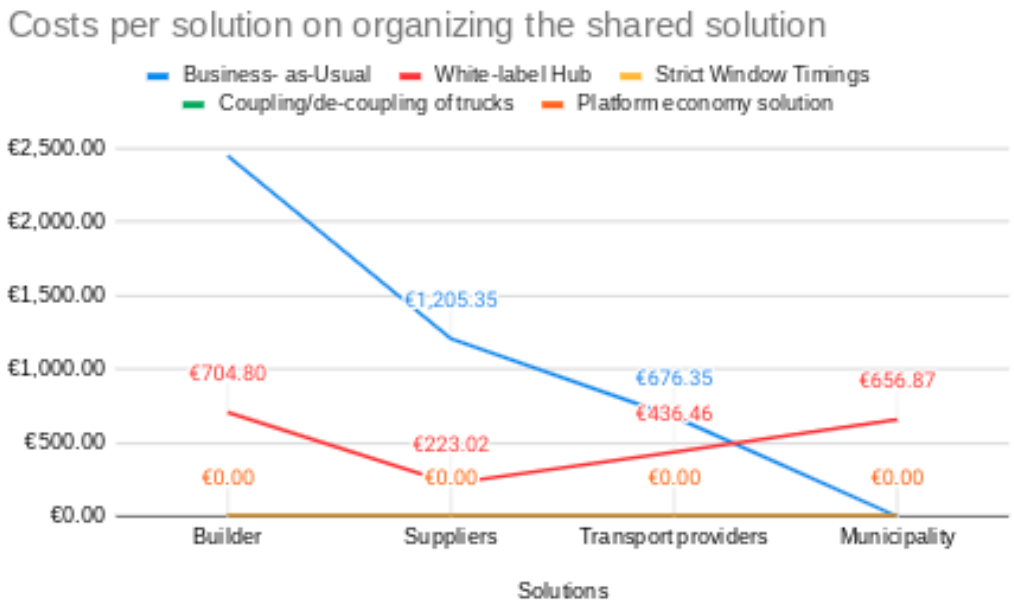


Figure 5.7: Solution organisation cost comparison

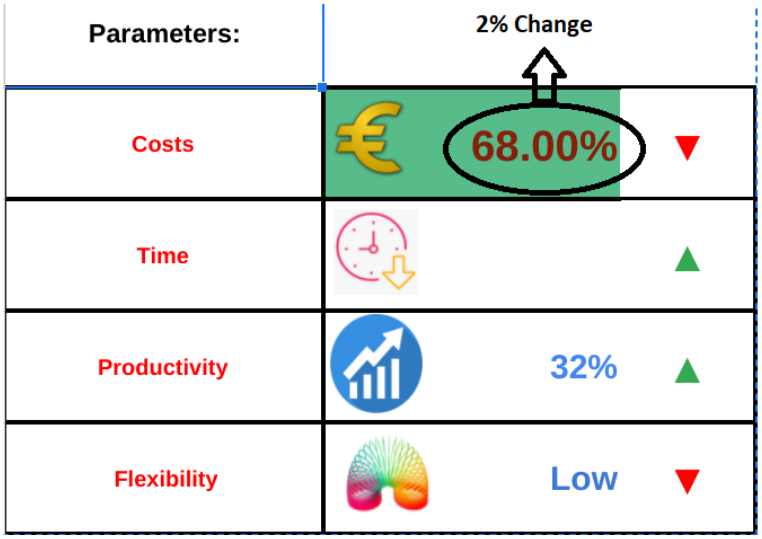


Figure 5.8: Parameters with added cost of organisation

5.2.3.2 De-briefing 1:

Following the first play-session, the break-out rooms would be closed & the players would return to the main room for a collaborative de-brief session.
This de-briefing is aimed to understand if the players have developed sufficient understanding for interacting with the platform and the various trade-offs presented.
The below questions are part of the de-briefing:

- Do you have any doubts in the game?
- Do you understand how to navigate in the game and what kind of trade-off parameters you are presented with?

5.2.3.3 Play session 2:

This session incorporates an actual game session with assessment to encourage the players to explore more aggressive solutions. To maintain the session flow, an added difficulty is introduced in terms of saving most emissions in addition to costs as opposed to only costs in the first play-session. The players are required to follow the similar process with an additional parameter of emissions in mind as depicted in figure 5.9.

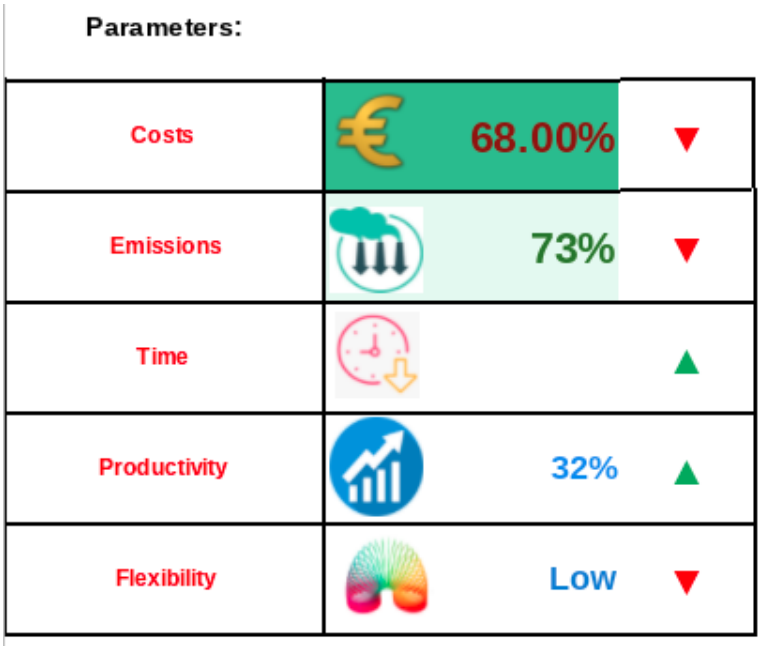


Figure 5.9: Emissions parameter added for second play-session

The players would be assessed based on the resultant total costs & benefits from the collaborative decision taen by each team.

5.2.3.4 De-briefing 2:

Similar to the first play-session, the players would return to the main room for collaborative de-briefing session. This session is targeted to understand the interplay of costs & other trade-offs on the choice of solutions for the players.
The captain from each team would answer the below queries from the facilitator so as to stimulate a discussion and analyse different line of thoughts from the participants.
The below questions would be part of the second de-briefing session:

- How did you arrive at this solution?

  - Which solutions did you explore?
  - How did you choose those solutions?

- How did the play-session go?
  - How was the discussion triggered in the game?
  - Were you able to analyse the trade-offs the decisions presented?

- Any improvement suggestions for the platform or the session ?

After the discussion, the winner for the session would be announced and a surprise cost-sharing session would be introduced by the facilitator.
The cost-sharing mechanism would be mimicked as a contract signing session by the winning team presenting 3 main clauses for the contract. This session would be held in the main room so as to present a demonstration of the negotiation process to all participants.

1. **Clause 1**: Share the cost of organisation in the chain. The participants are presented an option of negotiating their share in organisation costs since it would serve as an incentive for the actors to adopt these sharing solutions creating a win-win situation for all.

   The collaborative team would be presented with the total costs per actor & allocated costs of organisation out of those total costs for their chosen solution as depicted in figure 5.10 and figure 5.11 respectively.

Figure 5.10: Total costs for solution

   The allocated cost share for organisation is expressed in percentage and players are asked to negotiate the new percentage share for themselves in the chain & input in the required lines in the platform to view the impact. The organisation costs borne by municipality is not counted in the chain currently since they would be community-based costs & may not be specific for this construction case.

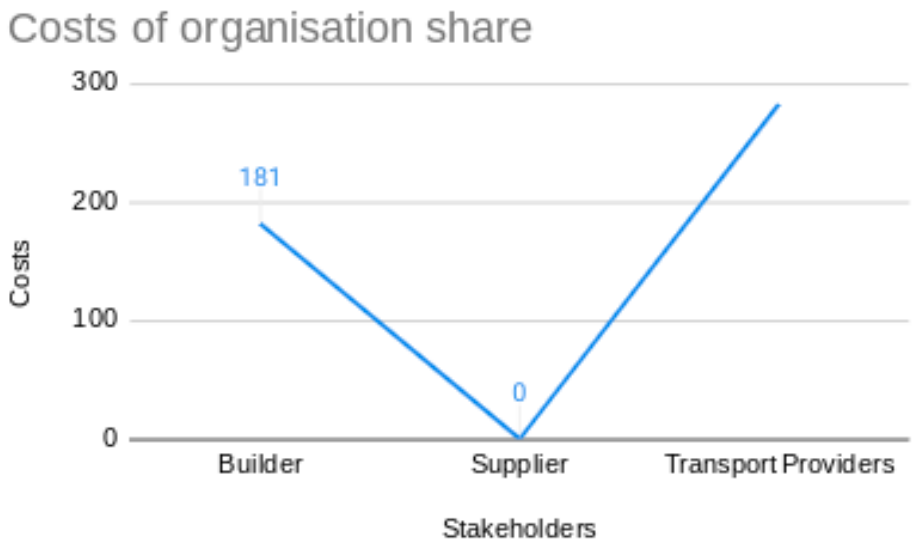


Figure 5.11: Costs of organisation share per stakeholder

A feedback in terms of costs change in graph is observed when the players try to reassign the percentage of cost share in the provided input boxes.

2. **Clause 2**: If the builder tries to communicate the plan for material delivery 2-3 days before, two more negotiation parameters would come in play namely Material costs & transport costs. **Rationale**: Costs charged to builder = Material costs + Transport costs Material costs = Cost of material+ warehousing costs+ storage costs The construction sector comprises of mostly Made-to-Stock products & given the adhoc order nature in the industry, the suppliers are required to maintain buffer stock of materials adding to storage & warehousing costs. In case of pre-order of materials by builders, these costs would be reduced at the supplier end & could act as a point of negotiation in the chain.

   Similarly, better plan communication in the chain would lead to more chances of capacity sharing for the transport providers , hence reducing operational costs at their end & hence, could act as a point of negotiation offered to their clients.

   But these negotiations are constraint by better plannability in the chain, and thus the input boxes could be activated only if the pre-planning option is agreed by the builder and shared by the parties by inputting the % cost reduction in green boxes as depicted in figure 5.12 .

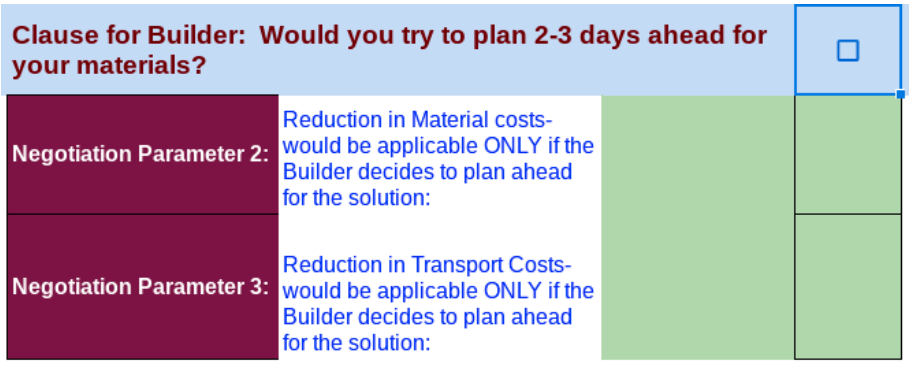


Figure 5.12: Negotiation clause 2 and 3

5.2.3.5 Session 3:

Creative solutions from other sectors are presented to the players to stimulate discussion & facilitate similar solutions for the construction sector as well.
Solutions from other sectors:

Zara: Establish standards for common materials manufacturing and enable bulk buying. Supplier companies could bulk buy the common material such as insulation, glass,etc. to drive down material costs.

IKEA: Kitting services could be implemented from hubs for the requirement on site.

Any creative solutions from your end?

5.2.4 Post-session

A collaborative de-briefing session would be held to evaluate the session impact on the players.
The following questions would be discussed:

- What was your learning from this session?
- How are game and reality connected?
- Were you able to assess the trade-offs and tensions presented in the game?
- Would you be interested to explore any of these solutions for your upcoming projects?
- Any improvement suggestions?

5.3 Conclusion of Practical Session Design

The chapter operationalizes the requirements and elements finalized in chapter 4 for overall session design. The section 5.1 explores the technology and elements with their respective sequence to be represented in the session. The parameters in the play-session depicts the various trade-offs summarizing the quantitative trade-offs and qualitative trade-offs of stakeholder depiction and tensions as summarized in section 4.2 and 4.3. The session is added with gaming elements with incremental challenges to adhere to the flow theory. Furthermore, following the scaffolding principle, the session was split into mini-sessions of smaller intervals each to assess the understanding of platform use and construction logistics concepts by the participants. The practical examples from the literature were also referred to finalize their depiction in the platform. On finalizing the depiction, an iterative process was utilized to arrive at a feasible platform and session design. The overall session design is depicted in section 5.2 with inputs and feedback provided to the participants at each stage of the session. The chapter concludes with a feasible session design targeted to create awareness for sharing concepts in construction sector.

Chapter 6

Evaluation

This chapter aims to answer the research question RQ4 and RQ5 regarding the effectiveness of the session on the players. The following sections describe the play session setting and effectiveness of the session as analyzed from the in-play session and collaborative debriefing session. This play test was used to refine the session requirements as advised by the participants which is then followed by an actual session depiction with industry players using a hard-thinking protocol.

6.1 Introduction

The session needs to be evaluated to understand its impact on the participants in the extent of attainment of goal of this project.

6.1.1 Evaluation Methodologies

Due to unavailability of direct literature for awareness session impact measurement, an assessment of serious games is utilized to justify the in-play session elements of the session. Assessment is defined as a assessing the level of learning goal attainment by the artefact by use of data (Bellotti et al., 2013). There are two types of assessment described in literature: (1) summative: the assessment is conducted at the end of overall session and tests the overall acheivements (2) formative: this type of assessment monitors the progress and failures of the participants and is present throughout the game.

In case of summative assessments, the most common assessment is the pre and posttest design. This framework is detailed by Mayer et al. (2014) in a quasi-experimental research design. This design follows mixed methods of data collection and analysis based upon the type of data to be gathered and the purpose of the overall game. The research framework formulates a conceptual model that evaluates the impact of background and learnerś perceptions before the game and its effect on the game session as well. The evaluation of the game is performed in a collection of pre and posttest session wherein a treatment is performed at a certain control group and the posttest measures the similar awareness results at the end of the session to evaluate the impact. However, the pre-test session could impact the validity of the overall impact on the participants and result in research bias (Bellotti et al., 2013).
Another most common methodology is the use of posttest only method using survey/questionnaire or tests to evaluate the learnings of the session. This method utilizes the quantitative evaluation and maps the learning of the participants on a scale to evaluate the impact of the game (Bellotti et al., 2013).
However, for the purpose of this project, only qualitative research design is utilized using data collection and data reduction methods. Due to the limited number of participants for the evaluation, a quantitative methodology might lead to inconclusive results due to high bias towards a singular opinion of a participant.

Inregards with this project evaluation, the transcript of in-play session and de-briefing interactions need to be analysed using qualitative analysis. Sutton and Austin (2015) describes qualitative analysis as accessing participants' thoughts and feelings that can enable development of an understanding of the meaning that people ascribe towards their experiences. Given the awareness raising goal of this project via experiential learning, the qualitative analysis would be suitable to understand via data collection in terms of interactive session transcripts and analysis to determine the effectiveness of the facilitated session and its integrated elements.

For evaluating the sessions for this project, coding approach method as described by Saldana (2016) were utilized. The transcript for the play-session is an observed process by the facilitator/ researcher wherein the different mechanisms of game-play help in drawing conclusions towards participants´ behaviour in a similar setting. The descriptive coding process of drawing specific conclusions from text could be utilized in this case and matched to the requirements of the session.
Meanwhile, for the session evaluation, the feedback derived from the collaborative de-briefing session could help in evaluating if the quality of session is helpful for the participants to effectively interact in lines of the session requirements. Since the questions asked in these sessions are more straight-forward regarding the detailing of the session, engagement and complexity, a mix of descriptive and in-vivo coding that stands for coding exact phrases or words from the text are utilized. Given each session duration is approximately 1.5 hours, the coding from the transcript would not result in many codes from the session, however it depends on the researcher. Hence, the coding to 2 levels, open coding followed by its division into sub-categories of requirements called axial coding would be sufficient for this project. Though, given the session is facilitated enough times and since the session would lead to different outcomes and interaction with each facilitation, a common criteria could be eventually derived to conduct the code analysis.

6.2 Play test Setting

A session was held with five participants that composed of branch organization representatives, serious game expert and supply chain experts. Since the players were aware of construction logistics solutions, the session was targeted to test the quality and realism of the platform to test its impact for the industry practitioners. The players assumed roles each of builder, supplier and transport provider belonging to the industry to mimic the interaction that the platform would facilitate in an actual session. This session was used as an input to improve the overall platform design and determine future research for the platform to create maximum impact for the industry.

The session was held for approximately 1.5 hours and facilitated extensive feedback from the participants. An introduction of players and a pre-briefing session was held for the first 30 min followed by the play session for about 30 min. Due to time constraints, the play session was cut short and the mechanisms were demonstrated by the facilitator to obtain valuable feedback on all aspects of the session.

The participants were divided into 2 teams at the start of the session each representing a construction project setting with builder, supplier and transport provider. Due to the lack of participants in the session, one of the participants played a dual role of supplier and builder in the team.

6.3 Qualitative Data Analysis

The session was transcribed and coded in Atlas.ti to derive necessary conclusions and improvement points for the final design of the interactive session. This session was particularly tested to verify the feasibility of the platform against the requirements stated in section.

An open coding approach led to about 23 codes in the transcript that were then reduced to code families using axial coding approach. These code families are associated to the objective and requirements of the session and hence, would be utilized to enhance the quality of the platform and session as a whole.

- Awareness of sharing solutions for construction logistics
- Interplay of trade-offs for these solutions in terms of qualitative and quantitative benefits.
- facilitating discussion regarding sharing possibilities
- tension between individual goals and team utility
- creative solutions explored in the discussion process

Collaborative debriefing session requirements:

- Playability of the session
- Realism
- complexity
- duration

6.4 In Play-session evaluation

The game session recording is mainly held for the first tutorial session wherein players are allowed to explore the game mechanisms. This session was held over Zoom call due to COVID-19 protocols. Since Zoom platform poses constraints in recording the break-out rooms, one team was assigned to a break-out room whereas another team stayed in the main room so that the recording could be performed for evaluating the effects of the game. The team in the main room was called Team A and their interaction of exploring the platform was transcribed and hence, will be used for evaluation in this project evaluation.

The composition of Team A was as follows:

1. Researcher in construction logistics from TU Delft playing the role of a supplier
2. Serious Game expert from TU Delft playing the role of transport companies
3. Representative from Bouwend Nederland (branch association for builder companies); expertise in logistics and role-playing builders in this session.

The link to the interactive platform in the Google Sheets platform was provided to the team and builder, the team leader shared his screen such that only one person could navigate through the sheet at a time. The team started with exploring the solutions in the platform along with the trade-offs presented at the top of the sheet:

"*So now we should we choose a solution. 00:05:46 Speaker 1 Is that the idea or yeah? 00:05:48 Speaker 4 I think we need to right? Yeah. 00:05:50 Speaker 1 00:05:50 Speaker 1 00:05:51 Speaker 1 So there is this, this info, sharing the hub and this is uh. I know so kind of sharing capacity on the way. Yes, that's a little bit different so I think. 00:06:02 Speaker 4 I think if you Scroll down uh again, yeah, then we have the solutions there. 00:06:07 Speaker 1 OK. 00:06:08 00:06:10 00:06:10 Speaker 6 They do nothing is solution one. 00:06:12 Speaker 1 Yeah, I always feel so good solution. 00:06:29 Speaker 6 The second one is white label huh? 00:06:31 Speaker 1 00:06:34 Speaker 6 So carried out by the city or something or should I imagine. 00:06:37 Speaker 1 Yeah, it should be somewhere in I think yeah*

on the on the. 00:06:40 00:06:41 Speaker 1 Boundary of the city, yeah. 00:06:43 00:06:46 Speaker 6 And I think. 00:06:47 Speaker 6 The figures at the end to 32%, then 73%, is is. 00:06:52 Speaker 6 The is the effect of the solution I suppose. 00:06:54 Yeah, yeah. 00:06:57 Speaker 6 Now we have strict window timings, meaning every supplier just comes in according to schedule. 00:07:04 Speaker 4 00:07:05 Speaker 6 But with their own vehicles....."

After exploring each solution and its working, the role of each player defined certain responsibilities to make these solutions work. The team started discussion regarding sharing of information of making these solutions work. At first, strict window timing solution was explored.
The discussion entailed characteristics of reluctance of change from traditional ways of working but trade-off of lower operational costs & option of cost-sharing in the chain seemed to drive the transport provider towards the solution.

"*Uh but in my perspective, I believe that right now. I already have my schedule set so setting a new schedule, depending on on what window. 00:11:18 Speaker 4 Uh time window is is defined might be difficult for me. So then what I would would ask Marcel is if I could get like eventually to to split some. 00:11:29 Speaker 4 The extra costs that I might have for that. 00:11:33 Speaker 4 Uh if but it's not going to. 00:11:36 Speaker 6 Be cheaper that's for sure. 00:11:37 Speaker 4 Yeah, I I don't think so. I don't at first at least. I don't think it would be cheaper because it would imply for me, changing the way I'm. 00:11:44 Speaker 4 Doing things yeah. 00:11:44 Speaker 4 Doing things.*"

Furthermore, information sharing among suppliers was encouraged by other parties in the chain to enable smoother operations. For this, a digital platform was discussed to be implemented and initial supplier agreed to share limited information that might be useful for consolidating deliveries.

The reluctance to change and information sharing also represent the tension between the perceived individual utility and team utility in a collaboration. This is an important trade-off that leads the teams to eventually seek an incentive such as cost-share to arrive at an synergistic solution.

"*From you guys to ask me is to give the information as to what I'm going to order some days in advance, so that you can plan optimally. 00:14:11 Speaker 6 And maybe you can combine so main question is am I so well organized in my in my design. 00:14:20 Speaker 6 In my 00:14:21 Speaker 6 Uh planning that I can send. 00:14:24 Speaker 6 You let's say 80% accurate planning a week in advance, making it up to 100% accurate in the in the 2 days in advance.*"

Also, creative sharing solutions such as sharing planning schedules with suppliers and transport providers was discussed in the session allowing better co-operation and further reduction of costs in the chain. The exploration of these possibilities could have added value to the last round of the session wherein the participants would be asked to discuss creative solutions that they might encounter in this interaction or triggered by the better chain co-operation.

6.4.1 Conclusion of in-play session

The interaction between the 3 participants does represent a realistic representation of interaction between the stakeholders in the chain and could be related to the problems and behaviours observed in the interviews of the adjoining research. Based on the interaction observed in the in-play session, it can be concluded that the interactive platform does facilitate discussion regarding the interplay and trade-offs of solutions and the implementation of solutions by triggering openness of the parties in the chain.

However, the team didn't proceed to the other parts of the game-play where they would found

the solution organisation costs & cost-share mechanisms explicitly mentioned in the platform. The participants were construction logistics experts except one and were able to understand the right optimism for working of the solutions. The participant who did not belong to the construction logistics field was still able to understand the interplay of trade-offs and display the discussion reality. Also, he mentioned that if there is a de-briefing session following the game session as planned, his position in the chain would be much stronger and would allow for a better judgement of the other parties in the chain as a whole. Thus, it could also be concluded that the game instills logistics focus to the discussion and a participant with lesser knowledge of logistics could benefit from the session and explore these costs in the chain as well.

"*Playing playing the role, playing the role of the logistic person that seemed feasible, but it made me think about it. So in that sense, the game was already working. If we were doing a debriefing after this session, which was supposed to be at around, I would already have reflections on my relation with the other parts of the chain.*"

However, this interaction is an indication of the effect of the interactive platform designed as part of this project. But given each project is different and experiences as well as knowledge of the participants, the interactions could go in another direction or result in a different outcome.

6.5 Overall session related evaluation

The collaborative de-briefing session was used to gather the general feedback on the mechanisms offered in the session & suggestions for improving the same for an actual play-setting with industry practitioners.

A pre-session brief was provided to the players comprising of basis of solutions and working of solutions in addition to the session play and timings. But little was communicated regarding the mechanism of platform since the tutorial was scheduled specifically for this activity wherein the players find time to explore the platform and feedback facilitated by it. However, the players struggled with navigating in the platform due to the multiple TABs in the file in the first session & suggested more walk-through in the pre-session brief. Suggestions included more visual representation of walk-through of the game and even a self-exploration of the game beforehand by the players individually.

"*Step of how the game is supposed to be played so border around. It is nice that you tell as there are lots of information and possibilities a bit of a more clear walk-through so.*"

"*And you should, I think, explain a little bit more out of tables in the diagrams work and how you can optimize it and then. 00:26:28 00:26:29 Speaker 1 Maybe let each of. 00:26:31 Speaker 1 The player play a little bit around with it to understand how things work and also then understand that one price goes up and emissions so. 00:26:40 Speaker 1 They will be like playing with yourself first on this this table and then have a discussion because you want to probably look what your optimum is from your perspective.*"

"*Just a bit more overview as to what was upcoming.*"

"*And you should, I think, explain a little bit more out of tables in the diagrams work and how you can optimize it and then. 00:26:28 00:26:29 Speaker 1 Maybe let each of. 00:26:31 Speaker 1 The player play a little bit around with it to understand how things work and also then understand that one price goes up and emissions so. 00:26:40 Speaker 1 They will be like playing with yourself first on this this table and then have a discussion because you want to probably look what your optimum is from your*

perspective."

Due to time crunch in the session, a quick walk-through was conducted to ensure the players understand the feedback from the platform and perform accordingly. After the walk-through,the understanding of the platform increased for the players but the feedback was to make the overall session a bit longer to provide the players more time to analyse the options. Given the walk-through, one of the players said that the interplay takes a bit more time to understand though however, he added that this is quite common with such sessions or game-plays that are conducted as per his experience.

"*Now I think what you should do is explain a little bit how we should organize our discussion. 00:23:04 Speaker 2 OK, I see. 00:23:04 Speaker 1 Because now we just went on and and and you said OK you can. You can maybe flip through the discussions and then see what the benefits are and then based on that see if you want to make it one of these solutions. Because now we first looked at OK, what is our position now? 00:23:21 Speaker 1 Uh, what is OK? And then we filled it in and we could of course have a feedback on that, and then maybe change it but. 00:23:21 Speaker 1 00:23:21 Speaker 1 00:23:27 Speaker 1 That takes a lot of time, I think.*"

"*OK, so do you actually say that the. 00:22:55 Speaker 2 Game takes a bit more time to understand. 00:22:58 Speaker 2 Because that will.*"

"*But it's I. I think it's a good. I think it's really nice because it should also be said. I think it's really nice to play this game now and have this feedback to to to make playing it better, because I last time that we played such a game and with Alexander and I think they they know. We have this this same difficulty in in getting the the the the the the goal of the game right and to to start start imagining what your role should be. So this is quite normal I I would.*"

Regarding the playability of the medium, the detailed representation of the costs & benefits without stated assumptions & values was overwhelming for few players. One of the players suggested to communicate the assumptions for each solution clearly beforehand so the participants might be comfortable with the realistic representation of the values. Also, maybe modify the numerical values to a simpler format. However, another player who belonged to the construction industry conveyed that the construction industry participants would like details & if combined with clear assumptions, these details would work for the session as it will be closer to reality. Rather the player based the complexity of the game on the multiple TABs and navigation required for the players.

"*I think the assumption is right, but it's it's hard. It's hard to 'cause all the assumptions are in your head that you develop this. So the the only thing is that you communicate a bit more about the the rules that are behind these. Uh, calculations that are behind and and it maybe it's enough, like Marcel said to just play around a bit and then see what happens when you.*"

"*I know the the the the building sector quite well and the people who works in it, and they love details. 00:46:53 Speaker 6 They do, yes. 00:46:55 Speaker 5 The the the more details how better they believe it. So you have to search for a balance between what Aaron says, and the details that makes it believable. Then the question. So in your perspective, do you think this is too complex or this is enough? 00:47:19 Speaker 2 00:47:21 Speaker 5 You're asking me. 00:47:22 Speaker 4 00:47:24 Speaker 5 Uhm it's 00:47:26 Speaker 5 A second. 00:47:32 Speaker 5 I think it's a little bit, too complex because you have a lot of details, but it's also quite complex because I have a lot of tabs. 00:47:44 Speaker 5 And and I have to select and select uh. 00:47:49 Speaker 5 Some things which I've selected before and as I said the explanation when it takes half an hour. Then it's too complex to play the game. So if I understand correctly, uh, if we had this the same information. 00:48:11 Speaker 4 In one tab. 00:48:13 Speaker 4 The number of information that the the quality and number of information that you have is fine.*"

Extracting feedback from the above conversation represents the feedback regarding quality of the session & the type of information represented, the player seems to be fine with it.

Regarding the impact of the solutions presented in terms of quantitative & qualitative trade-offs, the players were able to identify the overall impact of the choices made in the session & even though it wasn´t clear in the play session, the walk-through brought clarity regarding the mechanisms of the session.

"*Yeah, and and and. And then you could you could maybe? Plan a bit more optimal and then. To stay at the same cost because I understand that when I'm when I'm asking for certain time windows, you're. The efficiency in in the in the lorry goes goes down. So that would be, I think the The The The The best ways. But in in this. The vector scheme in this scheme what? What is that? What is then the? The impact.*"

The above statement was made by one of the players in the play session whereas the below statement was made after the walk-through and hence presented more clarity.

"*Also, we were assuming that we could role play the the role, adding the game and discussing from our perspective, but without the objective measurement from the game we were assuming ourselves how the impact. Yes, and this is these impacts are are the impacts of the system. So we were looking at. We were looking at our impact.*"

Conclusion of Session related evaluation

The Game related evaluation was the feedback provided by the players on the overall session conduction namely duration, facilitation of the session, quality & impact of the session & complexity. The main feedback received was regarding the low understandability of the game mechanism which was asked to be made more explicit during the pre-session briefing. Also, the assumptions accounted for the calculations of metrics displayed in the platform need to be included so the participants understand the level of realism for the play-session. Moreover, an explicit walk-through into the interplay of the session was requested due to complexity of the platform spanning to different tabs in the pre-session briefing to increase the understandability of interactive platform.

Regarding the quality & impact of the feedback received from the platform was deemed enough for the session though a bit complex & too detailed given the interest of the players. However, the current version was also considered fine since it is closer to reality by one of the industry representatives.

Therefore, it could be concluded that there are improvements required in the pre-session briefing regarding explicit instructions for the session interplay & probably the duration of the session to be extended or the materials to be provided to the participants beforehand so they have ample time to determine their optimum. Mixed feedback was received for the complexity in the game due to the real values from the system to keep the session closer to reality.

6.5.1 Improvements from play-test

The feedback received from the play test session with industry experts was used to achieve an improved session design. The main feedback during the session focused towards the understandability and explicit walk-through requirement for the platform. Also, even with a walk-through, given the many iterations presented in the platform, it becomes a bit complex to understand the interplay and different feedback in the game. Moreover, in terms of assumptions considered in the calculations, the participants would

be more considerable for the values presented in the platform. In consideration of these points, the improvement points taken up for the session are:

- The manual and the platform sample to be sent beforehand to the participants so as to understand and articulate the different feedback provided in the platform & maybe look for an optimum solution for their party. A video explanation is also considered for this improvement point.
- The pre-session brief to concentrate more towards the walk-through of the session instead of solution basis.
- The assumptions in the calculations to be communicated in the manual.

These improvement points are incorporated in the session & an improved session will be reported for this thesis project. Given the session was not validated with the actual industry players, a session could be organised for final evaluation which is a bit hard to organise given the holiday period for the construction sector. However, this project presents a hard-thinking protocol for the working of a final session.

6.6 Hard-thinking protocol

This section depicts a final session conduction via the use of a hard-thinking protocol by the researcher. Due to holiday season in the construction industry, the session could not be conducted for the industry players and hence, this would replace the actual play session of the players.

The hard-thinking protocol is reflective of the think-aloud protocol that refers to a data elicitation method known as concurrent verbalization. In practice, this method is performed via transcribing the subjects of the research while they say what they are thinking in their performing the task (G Linda & David J, 1995). In the problem scenario of this project, the evaluation with construction logistics experts did verify the awareness level achievement of the session, however due to multitude of player profiles present in the industry with no to limited knowledge of best practices in the industry and its working, the session could result in different outcomes each time with a different solution selected by players. These different outcomes could be inspired by internal beliefs such as financial-minded or an environmental conscious player or someone with working experience of the solution could be leaned towards the positive side of the sharing solutions. Since the actual session could not be organised with the target players, the researcher has tried to formulate an example session while assuming multiple roles in the session.

In order to model replicate a session with industry experts, different player profiles are depicted as noticed in interviews and an imaginary session is depicted utilizing the hard systems thinking of the researcher.

6.6.1 Preparation for the session

As per the main feedback of the playtest session, the manual and a sample game session would be sent to the participants the prior day to learn about the calculation assumptions & get acquainted to the platform since it takes a bit more time to understand at first.

6.6.2 Player profile

The participants of the session comprise of 6 players that would be divided into 2 teams of 3 people each. Each team would comprise of a builder, a supplier and a transport provider. For this session, a profile is attached to the players to understand the specifics of decision-making that go into play for

these sessions. The play session is described in view of a team and their exploration of appropriate solutions for the project.

Team A profile: The transporter in this team has worked in a project that employed a hub solution organised by a big construction company. They could identify the effects & advantages of increased load factor for the deliveries during the finishing phase of the project and this experience might affect their decision in the game.

The builder is a SME and is open to sustainable solutions for the sector as he does view cost-saving opportuntiies in the solutions.
The supplier is a SME and though wants to adopt these solutions but is not open to share data with competitors & wants to build long-lasting relationships with the other parties in the chain.

6.6.3 Play-session 1:

The team needs to attain the goal of saving maximum costs in this session. As presented with the input in the platform for costs & benefits data, the team decides to explore the Strict Window timings solution.

- The transport provider negotiates that even though the operational costs are lower, their costs would increase due to changed ways of working & might impact the current schedule and even require new organisational capabilities due to new expertise requirements.
- The builder is content with the trade-off provided by the platform regarding increased productivity but is a bit worried regarding the immediate delivery requirement in case of any uncertainties at the site.
- The supplier also stresses for better planning from the builder so that the delivery requirements could be met on time. Due to strict time windows, a high consolidation rate might be the target for transport providers & the supplier is not very flexible with data-sharing to the parties. A trust-sharing mechanism needs to be established for the suppliers to share required delivery data with the other parties.

The team decides to explore the different organisational ways for this solution & a much easier way is to use Uberfreight for materials delivery. Other supply flows presented the options of rented equipment via Floow 2 app, regional coordinator, smart waste collection & carpooling of subcontractors.Selection of this option adds organisational costs for the transport provider & reluctance for adoption of this solution is observed from the transport provider side.

Due to the small duration of first play-session session, the breakout room was closed & the team joins the facilitator & the other team in the main room for the first de-briefing session.

6.6.4 First de-breifing

This session aims at determining the understandability of the platform for the players & the various trade-offs presented in the game. A small discussion regarding solutions choice was discussed wherein Team A came to know that Team B had a representation of a big supplier opened up its online services to order or rent goods. They went for the platform economy solution and given the big supplier represntation in the team, they were able to save most costs in the chain. However, team A was motivated for the next round & explore more aggressive solutions for cost save.

6.6.5 Play session 2

The teams are again distributed into break out rooms with 10 minutes with a goal of saving maximum costs & emissions between 2 teams. Team A tries for more aggressive solutions in terms of both costs

& emissions & tries to explore the white-label hub solution on advise of transport provider. However, there are various options presented to organise this solution. They choose the below solutions options & try to discuss the various interplays in organising this solution.

- The builder is a bit reluctant as this solution would mean higher costs for him & stresses for cost-share with the supplier in the practicality since the chain benefits entirely in terms of logistics costs.
- The transport provider though is positive towards the solution but sharing of benefits with competitors in the chain could be a bit problematic and wanted more clarity from municipality in this regard.
- In view of Just-in-Time concept in mind, the supplier comes up with a solution of use of kitting services from the hub that they have heard about from the De Trip project. The kitting services concern the assembly of required parts to be utilized for the day and only those be transported in a package similar to IKEA´s idea. Since the supplier´s goods are transported from their trusted transport provider to the hub so sharing data between parties directly is eliminated and they have the regional co-ordinator to handle this aspect. However, the supplier is concerned regarding the handling and storage facilities at the hub as this solution would require double handling of goods & might expose them to damages affecting delivery quality. Hence, the supplier would want to check on the insurance services offered by the municipality in this regard.

The team now tries to focus on the emissions as well and noticed that this is the second most emission-saving solution after the strict window timing that was explored before. They also try to explore other supply flows such as reimbursement of payment charges to the subcontractors for public transport , using digital apps for ordering, smart returns, etc. Given the risk of a few years time required for the readiness of a hub by the municipality, the other solutions are quick to implement for their upcoming project & hence raise awareness for the solutions.

6.6.6 De-briefing session 2

The teams are now back in the main room with the facilitator & the team B went with the same solution as in the first round, team A won the round with most save on costs & benefits and proceed towards gain-sharing mechanism.

The solution exploration is discussed in this round for both teams & more information from municipality representative is requested towards the hub solution. Also, team B utilized their advantage to leverage a good solution & possibilities of such a platform & volume of usage was discussed.

6.6.7 Gain-sharing mechanism & collaborative session 3

The team A negotiated on cost-share mechanism for all 3 parameters wherein the builder negotiated for cost-share in operational costs of using hubs demanding 30% pay by the supplier due to reduced costs of storage. Also, the builder agreed to the clause of planning ahead of 2-3 days in advance & negotiated concessions of 20% in material costs from the supplier & even the transport provider offered 10% concession on transport costs hence reducing overall chain costs.

6.7 Improvement for Overall Session

The improvements are suggested in this section derived from the play-test and hard-thinking protocol assessed in terms of conduction of an actual session. A similar problem noticed in the session facilitation is the multitude of solutions and their combinations to be compared. The players may not find

sufficient time to explore all the solutions in the game. Hence, a reduced prototype with lesser solution combination can be implemented. Also, even though the session facilitates discussion for solution, a much clearer system interplay was pondered upon by the players in the play-test session as it leaves many possibilities open such as location of hub in a bigger city as for a project at the opposite end as hub might find it unattractive though the storyline says otherwise. However, it might reduce the external validity of the product. This idea could be extended to the further recommendations of this project.

The session facilitation time was set at 1 hour currently but due to the complexity of the tool, it was extended to 1.5 hours approximately. Thus the overall time needs to be extended to 1.5 hours for the session altogether to take care of any technical or facilitation issues.

The most attractive solution in the tool seems to be the strict window timing, however it pushes many other set-up costs such as transport providers needs to adopt new technology or experience increased workload due to the introduced policy. Also, it forces the idea of pre-planning for all players and given the uncertainty prone construction sector, trade-offs such as delivery uncertainty may be higher for this solution. However, these parameters are currently not modelled in the game and may be facilitated in the walk-through of the game and taken up for further research.

6.8 Conclusion of Evaluation

The chapter aims to evaluate the impact of the overall session depicted in section 5.2 and the extent of objective fulfilled by the project as determined in the section 1.3. The session was play-tested with construction logistics and gaming experts that role-played the industry players to measure the impact and quality of the session. Since the participants possessed advanced knowledge of concepts beforehand, the quality of the session was measured against the theoretical requirements such as to deliver a feasible product for the industry. A qualitative analysis was performed to evaluate the session feedback and identify improvement points for the session design.

The improved design was targeted to the tested against industry players to measure the actual impact of the session but due to time constraints of the project coupled with holiday season in the construction sector, this couldn´t be held. However, a hard-thinking protocol is presented in the section 6.6 drawing personality types from interview analysis and play-test session and mimicking the course of a real session facilitation. The detailed protocol depicted in the session depicts the collaborative thinking of a group versus individual utility and striking a balance between these two factors for each represented stakeholder.

Chapter 7

Conclusion and Recommendations

This section is focused on reporting the conclusion of the project and providing recommendations for the future research. The research questions are answered in this section followed by conclusions of the project and contributions to the research. The recommendations are also added at the end to include further interplays or ways to raise awareness for the sector.

7.1 Conclusion

7.1.1 Findings

RQ1: What are the current challenges/ bottlenecks for SMEs in construction logistics ?
The SMEs form a crucial part of the construction sector representing approximately 99% of the EU companies. The temporary organisation of each project poses most inefficiencies in the sector however pilot projects have been adopted wherein the companies could overcome these inefficiencies by data-sharing in the chain. But the solutions render ineffective in most projects due to conscious nature of data-sharing by these companies since their competitiveness lies in the highly specialised knowledge they possess. Also, these solutions require high investments that pose financial limitations for the small and medium companies. Moreover, these inefficiencies are used as a service model by these companies wherein clients are charged extra if the shipment is required immediately or if the full truck load is not attained. These companies also thrive on the long-term relationships with clients and even some of the builders tend to drive themselves to the suppliers site in vans to pick up supplies thus, coupling work with relationship building with the suppliers ensuring good service. However, this business model of SMEs hinder the adoption of solutions in the chain. The upcoming policy of Green Deal 2025 requires effective logistics practices in the chain targeting lower movements of vehicles in inner city areas. Thus, the sector needs to adopt collaborative solutions to address these new regulations and would mean focusing on sharing capacity in the chain. This would require increased sharing practices in the chain in terms of truck capacity and data as opposed to current practices of SMEs. The interviews indicate that the SMEs are aware of these required changes but would require more insights on the impact of these solutions for individual parties in terms of business case.

RQ2: What are the session requirements that would be utilized for raising awareness for sharing concepts in the construction logistics chain?
The session aims to fulfill the requirements of presenting a business case per actor for the SMEs as indicated in the adjoining research of this project. The session tries to create an experiential learning for the participants where all parties could collaboratively explore the solutions and its impact and hence understand the each other´s perspectives in terms of implementing and working of these solutions. In addition, the conduction of the session requires to be engaging to keep the participants interested. Thus, apart from technical requirements, the session requirements involve engagement theories such as flow, scaffolding mechanisms and serious gaming elements such as scoring to increase engagement in

the session as well as let participants explore more aggressive solutions. A compilation of engagement theories and technical requirements resulted in 12 design requirements for the session described in section 4.1.5.

RQ3: Which sharing solutions would be appropriate for the SMEs in construction chain?
The solutions discussed in the project are based on two main concepts: Shared economy mapping as per Muñoz and Cohen(2017) obtained from the adjoining research & requirements of Green Deal 2025 for Rotterdam city. Also, the solutions presented need to be of integrated type constituting of all supply flows to the site due to construction work requirements. Due to financial limitations faced by SMEs, the organisation of these solutions is required to be handled either by municipality or need to be a collaborative one such that all parties in the chain are incentivised to go for the solution.
In consideration of the above requirements, the solutions proposed in this research are integration of supply flows to the site and comprise of collaborative solutions that are either existing such as digital platforms or require organisation by municipality. These solutions involve use bundling solutions such white label hub with all facilities present on site, white label trucks that involve bundling outside inner city areas and rest supply flows organised via carpooling or rental solutions and Marketplace organised by big suppliers that have existing digital portals or spaces as depicted in section 4.4.

RQ4: How to design and evaluate the interactive session that raises awareness of sharing concepts for SMEs in the construction supply chain?
Based on the prescriptive process of product design by Dym et al.(2009) in combination with requirements defined in the section 4.1.5, an interactive session was designed for construction sector to raise awareness for sharing concepts in the chain.

The overall session involves mainly 2 parts:

- Tool design
- Session design

The tool design involves the choice of platform, elements for discussion to be presented such as solutions´ details, trade-off parameters and cost-sharing mechanism. A simpler interactivity with the tool is also important for the users to focus most time on discussion rather than understanding the tool navigation. The iterative process design concentrated on the elements and promoting simpler interactivity with the tool for the participants.

The second part of the session was how to facilitate discussion and reflection for the discussion facilitated by the interactive trade-off tool such as to promote experiential learning from the session. These concepts involved use of scaffolding mechanism, flow theory to increase engagement for participants and gaming elements such as goal assessment to measure understandability of the play session by participants.

The session is designed to facilitate collaborative discussion in the play-session and feedback on the tool-related feedback in the collaborative de-briefing in presence of all participants. The evaluation of the session is recommended to be performed using pre and post assessment of the participants in the session. The pre-test would verify the construction logistics knowledge of the participants and ease of working with the solutions. The post-session would have targeted questions towards the discussion evaluation and post session knowledge of solutions and their willingness to adopt/discuss them in upcoming projects. Since, due to indefinite system interplays in the tool, the discussion would result in a different direction in each session , hence a qualitative analysis approach would be adopted to validate the session impact upon the participants. The questionnaire in the collaborative debriefing would be formulated to verify the performance and knowledge of the tool for the players and also gathering feedback regarding the session facilitation itself. This qualitative analysis would be

performed using the open coding and axial coding approach to validate the session discussion against the objectives of this project.

RQ5: What was the impact of the session on the participants?
The impact of the session observed in the playtest with the construction logistics experts summarized in sections 6.3 does indicate a raised awareness for participants for collaborative working of the solutions.

While considering at the solutions and various parameters presented in the tool, the participants in the play session were able to discuss and negotiate the basis of going for a collaborative solution and the changes in ways of working for them such as data-sharing and new technology introduction causing reluctance to solution adoption. However, the team was able to choose a common solution despite trade-offs made my each party in the chain when cost-sharing opportunities were discussed thus indicating the incentives for arriving at an synergistic solution. Also, given the unavailability of logistics focus in the sector, the session instilled logistics knowledge to the participants in the sector hence considerations of optimising the chain via sharing opportunities. Thus, a participants with variations in levels of logistics knowledge could even benefit from the session. The trade-off feedback from the tool was lucrative in the discussion and channelled the discussion towards the areas of logistics and site productivity.

The calculations present in the tool are closer to reality and allow the participants to even utilize actual business values such as change in charges for transport for the session, thus providing a sense of realistic collaborative discussion with the parties.

However, navigating with the interactive tool is a bit complex and takes some time for the participants to understand, the first play by the participants could be confusing. In consideration of this effect, many instances of tool experience need to be facilitated for the participants such as in pre-session briefing, tutorial and even as a preparation material for the attending the session to obtain maximum impact.

The above answers provided to the sub-questions aim to answer the main research question articulated to achieve the objective of this thesis project.

7.1.2 Project Conclusion

The increased urbanisation leading to more transport movement & upcoming Green Deal 2025 restricting entry of construction transport poses immense challenges for the construction sector since they are two opposite streams. The challenge of temporary project organisation for the construction sector deems it a it difficult to adopt innovative solutions in the chain. Though big companies have organised hub solutions, but the SMEs in the sector suffer from financial limitations of organising these solutions. Also, an absence of impact of these solutions in terms of business case makes them reluctant to implement these solutions. Thus, this project has tried to raise awareness towards the openness of these industry players for the sharing concepts int he chain leading to reduced costs & emissions.

A collaborative session with main stakeholders in the chain simulating a business case for the participants was identified to be held as an awareness session. The requirements of the session were defined and Google sheets was chosen to be sufficient for interplay of trade-offs for the solutions offered for exploration in the tool. A play-test session held with the construction logistics experts concluded with feedback of raised awareness towards the solutions & facilitating discussion for the solutions mechanism in reality in the view of trade-offs presented in the session. Currently, the session incorporates real values in terms of costs & benefits represented whereas gaming elements were utilized to increase competence & flow of the session. However, given the real values used in the platform, the players deemed it a bit more complex & could be improved with simpler values & more definitive systems

interoperability of the elements pointing towards a serious game. This would be included in the future recommendations of the project.

7.2 Contribution to scientific research

The interactive session and platform could be considered as a unique product to raise awareness for effective logistics solutions in the construction sector. The business case presented in terms of costs and benefits of capacity-sharing solutions is a contribution to the scientific literature of the sector. The current scientific research in the field is concentrated upon usage of construction hubs used for specific projects and this project has concentrated upon publicly utilized facilities targeted for use by SMEs in consideration with providing a business case for their efficient use. In addition to the business case, the gain specifics of the actors are articulated and presented as cost sharing concepts for the chain such as gain-share on material storage costs at supplier side or capacity-sharing in transport could lead to decreased overall costs, emissions with increased productivity in the chain and benefit the industry.

7.3 Limitations

The limitations of the project mostly lie in the characteristics of the construction sector itself and parameters considered for cost calculations. Firstly, the project assumes a simple make-believe case for calculations with representation of limited stakeholders but in an actual construction project, a lot more stakeholders are present. Also, the cost values used for the impact calculations would vary per project due to the multitude of companies offering different rates to clients in the sector and are also dependent on the project requirements. Furthermore, the quantitative survey in the adjoining research received low response from the sector players and may require a reconfirmation of the values before an actual play session with the industry players. In addition, the activity based costing approach applied for calculation rather takes into account mostly the movements of the transport but due to missing data for administrative activities at the consolidation points could not be added in the cost parameters. Furthermore, the companies could face organisational changes due to new competencies required due to technology adoption that may lead to additional costs towards hiring, training costs and time lost due to adapting to new technology (Baalsrud Hauge et al., 2014). These costs could not be counted in the model and hence, the current calculations are indicative of the operational costs and set-up costs for the actors.

Secondly, the session could not be play-tested with the actual industry players to measure the real impact of awareness among industry practitioners due to holiday season. However, the current evaluation involved in the project was representative of an actual session where the participants played the roles of the industry practitioners but their expertise in construction logistics sector could lead to bias towards the acceptance of the solutions. Moreover, a different discussion dynamic with more or less resistance could be observed towards the solutions when the session is conducted with industry practitioners leading to more practical discussions and hence, testing validity of the project. Also, since the playtest could be organised only with limited number of participants, a more robust analysis of the impact could not be performed for the session. This could have been a value-addition to the project since the session is designed in a way that could lead the discussion to different course in presence of different category of players with variation in logistics knowledge.

In order to reduce the second limitation, a session with the industry practitioners is considered to be organised by the researcher in the coming weeks but may depend upon availability and responses from the professionals.

7.4 Recommendations

The interactive platform designed for the session represents a make-believe case for the industry which is a simplified version of an actual project. A further representation of this project findings could lead to two directions: towards reality & towards simplification through gaming. These two approaches are discussed in detail below:

- The basic data & activity-based costing approach could be modified for a particular project to represent case-to-case analysis & help stakeholders with more practical insights for the solutions. This method would be more close to reality.
- Another approach as suggested by Baalsrud Hauge et al. (2014) is to use serious games for increasing awareness towards collaborative solutions in logistics. The systems interoperability such as delivery uncertainity, regional collaboration for transport, stricter policies, etc. is to be more focused upon rather than real values. A further iteration of this project could utilize the business case basis to determine simpler values in a digital game setup that could serve the similar purpose & might even eliminate the need of a facilitator.

Also, as per Baalsrud Hauge et al.(2014), many system interplays appear when different parties in the chain share resources. But representation of all these interplays complicate the play session and could be restricted Baalsrud Hauge et al. (2014) and hence, the system interaction in this project has been limited to trade-offs and cost-sharing mechanism. A further iteration of the project could include the below interplays:

- Unavailability of shared resources for some orders (Baalsrud Hauge et al., 2014).
- Definite information flows for the sector could be included regarding who needs to given what information.
- Stricter policy solutions could be integrated such as inclusion of emission reduction plan for projects in the tendering phase and permit approvals. Policies such as BLVC (Bereikbaarheid, leefbaarheid, veiligheid en communicatie) applicable in Amsterdam & Utrecht that focus on four important themes of Accessibility, livability, safety and communication (*What is BLVC? | BLVC*, n.d.) could be one such example that motivates parties to arrive at best eco-friendly solutions in the session.

An indication of a serious game flow with a few system interplays is shown in figure 7.1
In terms of business case calculations, a more realistic representation could be obtained for solutions when deep-dive is performed in the operational activities of each of these solutions.

- Intra-project data sharing to also be encouraged and bundling at source if possible could present more benefits for the sector and could be included in the business case calculations.
- The inclusion of costs of new technology change in terms of training hours for employees or hiring process due to new competencies creation could be added in the business case calculations.
- Costs of organisation of solutions present assumptive values in a few parameters due to data availability limitations and need to be verified from the industry players if they are indicative of the actual values.

7.5 Reflection

In this section, a reflection upon the academic, company and personal perspective is presented upon the conduction of this thesis project.

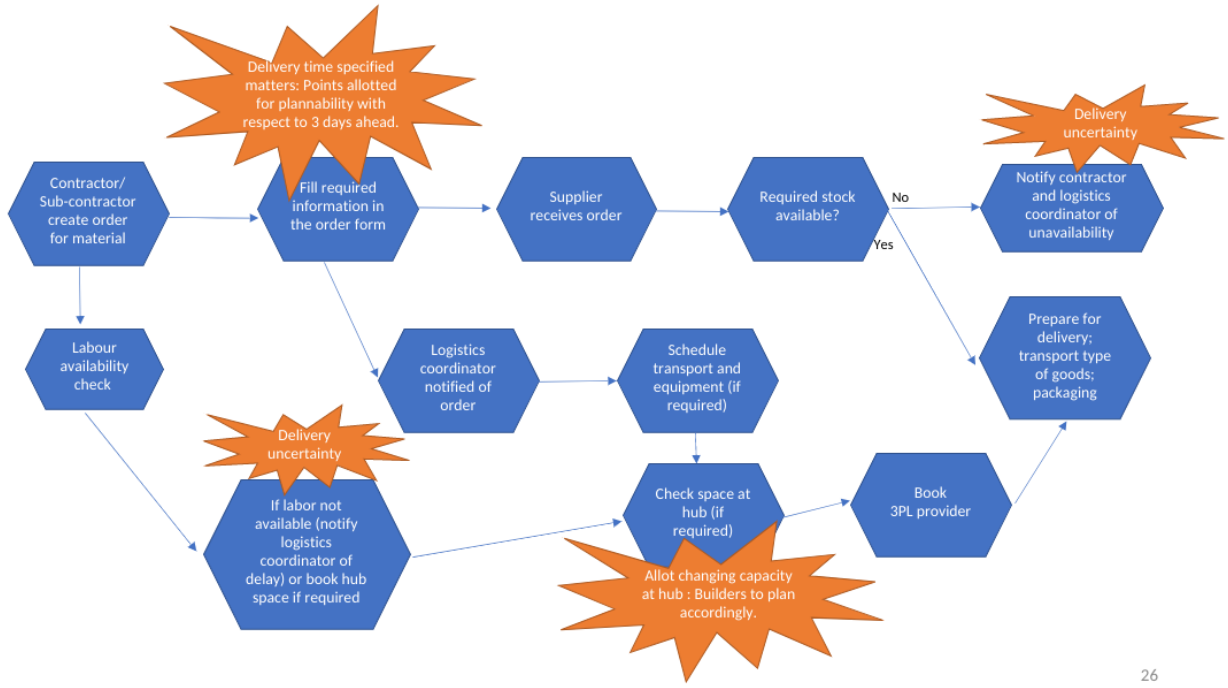


Figure 7.1: Serious game idea with system interplays

7.5.1 Academic Reflection

The academic journey for the thesis started with understanding the basics of the construction sector and its supply chain. The challenges regarding multi-supply flow coordination with multitude of stakeholders in the chain pointed towards the current non-innovative supply chain practices of the sector. In perspective of presence of highly specialized SMEs in the sector, the better understanding of the awareness level in the industry was important. The interview assessments in the adjoining research indicated that the SMEs were aware of the solutions itself but the lack of awareness towards the implications of organising and collaboration for achieving these solutions and their impact led to non-adoption of these practices in the chain. Hence, an experiential learning method such as interactive session, serious game, etc. was explored where players could collaboratively explore the impact of these solutions.

The play-test exercise with the construction sector experts proved very useful for the overall session design improving the overall quality of delivery of the thesis. The switch from serious game to an interactive session insight was decided based on this evaluation based on the feedback obtained from the industry experts.Though the initial direction of the thesis went into creating a serious game, the realistic representation of costs and benefits coupled with indefinite system interplays depicting reality mechanisms wherein players are presented with negotiating choices leaned towards an interactive trade-off platform. But the overall objective of raising awareness towards the collaborative working was attained as concluded in the evaluation session and thus, the researcher decided to stay with the prototype. However, the research did involve certain requirements targeted for serious game purpose that are summarised in the recommendation section of the research.

7.5.2 Company Reflection

This project was part of the construction logistics research conducted at Hogeschool Rotterdam funded by TKI Dinalog. The adjoining part of the research focused on mapping the business models of the companies in the construction sector using interviews and surveys. These researches were master thesis

project conducted by students at Hogeschool Rotterdam and TNO and served as basis for solutions identification appropriate for SMEs in the sector. Moreover, it helped in deeper understanding for the SME practices in the sector and guided towards the identification of right trade-offs to be presented for the impact of these solutions. In addition, the practical knowledge of the external supervisor helped immensely in understanding the supply chain practices in the sector and feedback for the platform design on parameters and elements to be included. Moreover, through the company network, I was able to evaluate my session design with the industry experts that allowed for the assessment of this project and improving its quality.

7.5.3 Personal Reflection

As a personal reflection towards conducting this thesis project, I would like to conclude that I thoroughly enjoyed it. Though it was difficult at first to understand the complex practicalities of the construction sector being an outsider, the guidance obtained from my supervisors regarding the resources and understanding of the concepts proved quite useful. Also, the insights presented in the interview sessions in the adjoining research proved most useful to gain practical knowledge of these complexities. The thesis was divided into three overlapping phases : Understanding of the sector via literature review and interviews, identification of solutions and session design. After gaining sufficient understanding of the supply chain practices in the construction sector, devising the solutions were easier since many interviewees indicated these solutions or they were present in previous researches. However, the raw data related to costs and benefits calculations was lacking and hence, a common warehousing data regarding time and costs was utilized here. The most enjoyable time spent was the design of the platform reiterating the design to attain the right prototype. Initially, the idea was to develop a serious game but however, the representation of realistic business case leaned it more towards reality. Hence, the session idea was articulated since it fitted the description of prototype better. But this change in idea did take some time for me to adjust to that affected the duration of the thesis since the thesis report required to be modified accordingly. However, once a sufficient conceptual understanding was established for the idea, the thesis report writing seemed easier due to the clarity of idea for the researcher.

7.6 MOT Relevance

This project deals with enabling the SMEs in the construction supply chain to explore innovative collaborative solutions and their effectiveness for the chain. Due to the upcoming Green Deal implementation across Netherlands that would allow only restricted movements of construction vehicles in the cities require better logistics management practices that require exploration of digital solutions leading to new social & economic environments for the parties in the sector.

The Management of Technology course taught at TU Delft corresponds to this idea of analysing business operations in view of current & future capabilities for the organisations. Moreover, one of the main objectives of the course deals with the technological procurement needs & its analysis regarding developing the capabilities in-house or in collaboration with outside parties or via acquiring or licensing. A similar analysis has been conducted via this project wherein digital technologies leading to better capacity-sharing have been provided as solutions for the challenges faced by SMEs in the chain based upon collaborative sharing practices. This project aimed to evaluate the company readiness extracted from the current business models of these SME companies and proposing appropriate low-cost solutions due to the financial implications faced by the SMEs that was highlighted as the major challenge for them.

The learnings of the specialisation courses followed through the program namely SEN9720 Logistics and Supply Chain Innovations and SEN9725 Supply Chain Gaming served as the basis of this project. It

helped me to identify the problems in the construction supply chain and provide appropriate solutions and design methodology for the interactive session presented as an output of this project. The course Research Methods (MOT2312) equipped me with the required knowledge to conduct the literature review and identify the right problem for the sector and address it in the project. The quantitative analysis method used for evaluation was also a practical application of this course learning. The course MOT1435 Technology, Strategy and Entrepreneurship helped me to assess the business ready level of these companies and suggest applicable solutions to change according to the new regulations in play.

Thus, the learnings from the courses followed in the MOT program helped in conduction of this thesis and overall relevance of technology change and new practices for SME companies to achieve supply chain efficiency for the sector.

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Appendix A

Session Manual

Storyline:
¨You are tasked with constructing a hotel on the Port of Lotterdam and the project is in its Finishing phase that would take about 1 week to finish. The municipality of Lotterdam is planning certain restrictions for construction projects and a table discussion is held among the builder, suppliers and transport providers of the project to collaboratively choose a solution for organising logistics to comply with the upcoming policies. Most of the companies involved in this project are SMEs (or serve as clients/suppliers for SMEs) and are particularly worried about this since these are specialised companies and are quite wary of transparency of costs and benefits that they would achieve by adopting certain solutions.¨ The construction site has 5 supply flows coming to the site:

1. **Material:** Palletized goods need to be collected from 2 suppliers located in the same industrial park (3 km) on tractor-trailers (max. Euro-pallet capacity: 33).
2. **Human Resources:** 3 subcontractors need to come to the site and the reference distance point is taken as P+R (Park+ Ride) which is located about 6 km from the site.
3. **Equipment:** Equipment is hired from a transport provider situated 4 km away from the site.
4. **Waste collection dumper:** Construction site has accumulated waste from the activities. The waste needs to be handled.
5. **Information:** This represents the information flow coordinated via an independent party appointed via the builder for the project or the municipality for the region.

The session offers quick solutions targeted at sharing truck capacity to help your business better prepare for the upcoming Green Deal 2025.

Your task is to explore the construction logistics solutions offered in the game and analyze their associated quantitative and qualitative effects and understand the negotiation or interplay you might encounter when selecting the solution.

Prerequisite knowledge:

- Basic understanding of how the construction sector works such as characteristics of the industry, phases of construction and required supply flows to a construction site.
- Basic logistics knowledge: understanding of storage costs, transport costs, handling costs, etc.

Equipment required:

- Laptop for each player if played online.
- If played in a physical environment, laptop /computer with projector.

How to Play:
Link to the platform could be found here.

1. Game will be played in 3 sessions followed by a debriefing session after each play session.

2. Players would be distributed into 2 teams of 3 players each and the game would be coordinated by the municipality. The teams would be asked to choose a team name and each player would be assigned a role of either construction builder, supplier and transport provider in the team.

3. The builder would be appointed as the team leader and would possess the following responsibilities:

   - Keep track of solutions explored in the game.
   - Briefly describe the play session to the game coordinator in the de-briefing sessions.

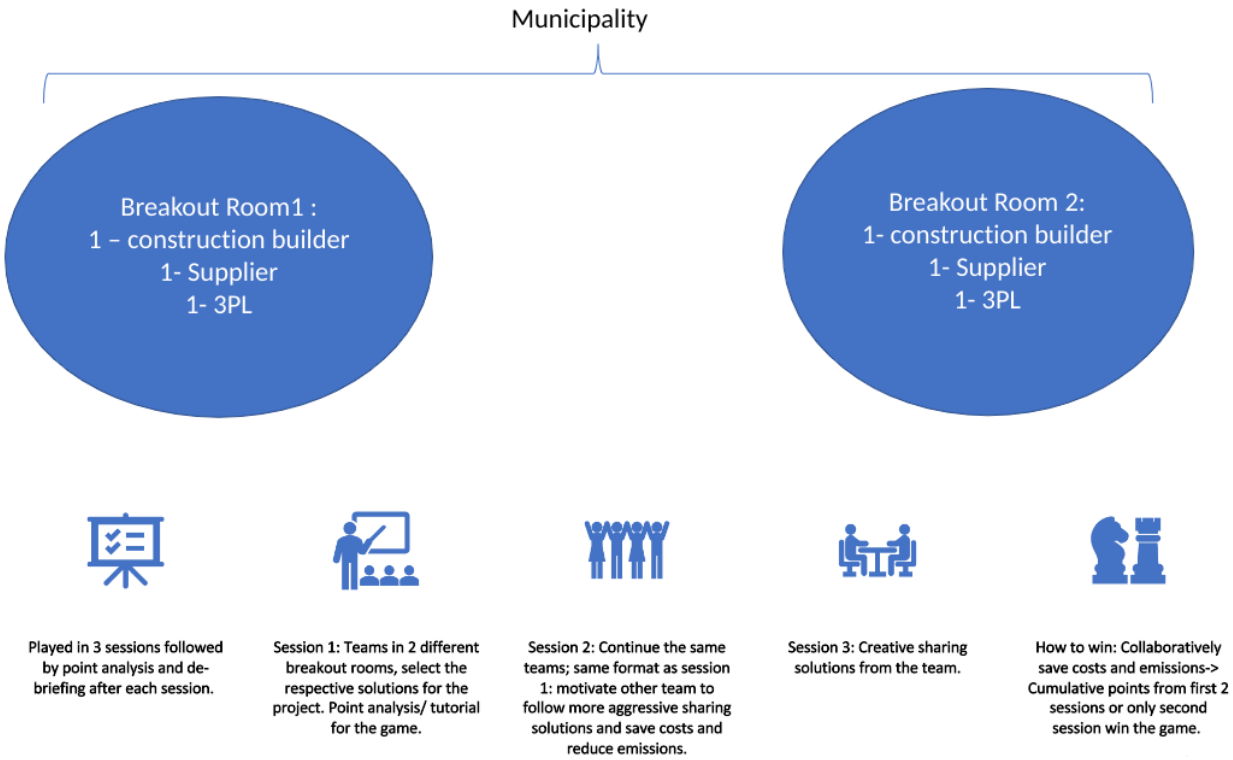

Figure A.1: Overall session

Play Session: In the play sessions, in addition to the presented solutions, innovative sharing solutions could also discussed that could help in optimizing the chain.

1. Step 1: Municipality passes a policy for the play session.

2. Step 2: Session facilitator to provide the EDITING access for the game to the team leader. Teams are assigned to different Break-out rooms for the next 2 steps.

3. Step 3: **Choose Solution:** Go to TAB play session. The below decision parameters are displayed in the platform:

Figure A.2: Session agenda

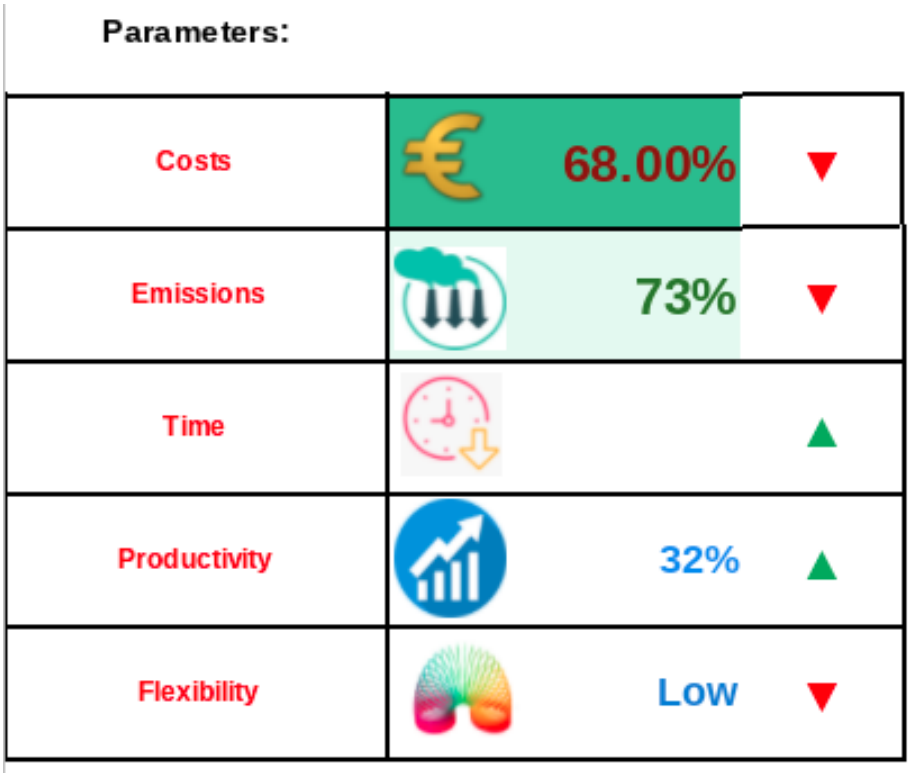

Figure A.3: Parameters in the play session

- **Costs:** The costs include transport costs, storage costs, waiting time and handling costs for the material from the suppliers.
- **Emissions:** This parameter represents cumulative emissions of CO2, NOx and PM10 emissions.
- **Time:** This parameter represents the lead time for activities in the construction logistics such as material loading time, material unloading time, waiting time at hub, waiting time at construction site due to restricted/open space.
- **Productivity:** Productivity at construction sites stands for acceleration in production time due to improved coordination in the construction activities and good internal logistics

enabling availability of all flows at the site at the same time. Productivity is viewed as a profit field for the builders as it leads to less delay in construction project overall and low spend of construction costs leading to better margins.

- **Flexibility:** This field could imply different meanings for different roles in the game.

Table A.1: Flexibility parameter criteria

Role	Implication of Flexibility field
Builder	Builders are currently ordering the material and supplies on adhoc basis following the today for tomorrow model, but if a solution needs to be implemented successfully, a better plannability is required.
Supplier	Suppliers are specialists in their particular products and are apprehensive regarding the data-sharing with their competitors, but if a solution is required, they need to be ready to share this data amongst their competitors.
Transport Provider	Transport providers may need to share their gains with other competitors and might even face restricted movement such as regional movement in a few solutions.

The SME parties in the chain thrive on trust and good relationships with their customers wherein the builder likes to visit the supplier personally and conduct their work as well as build stronger business relationships . But this visiting frequency might reduce if they adopt the sharing solution.

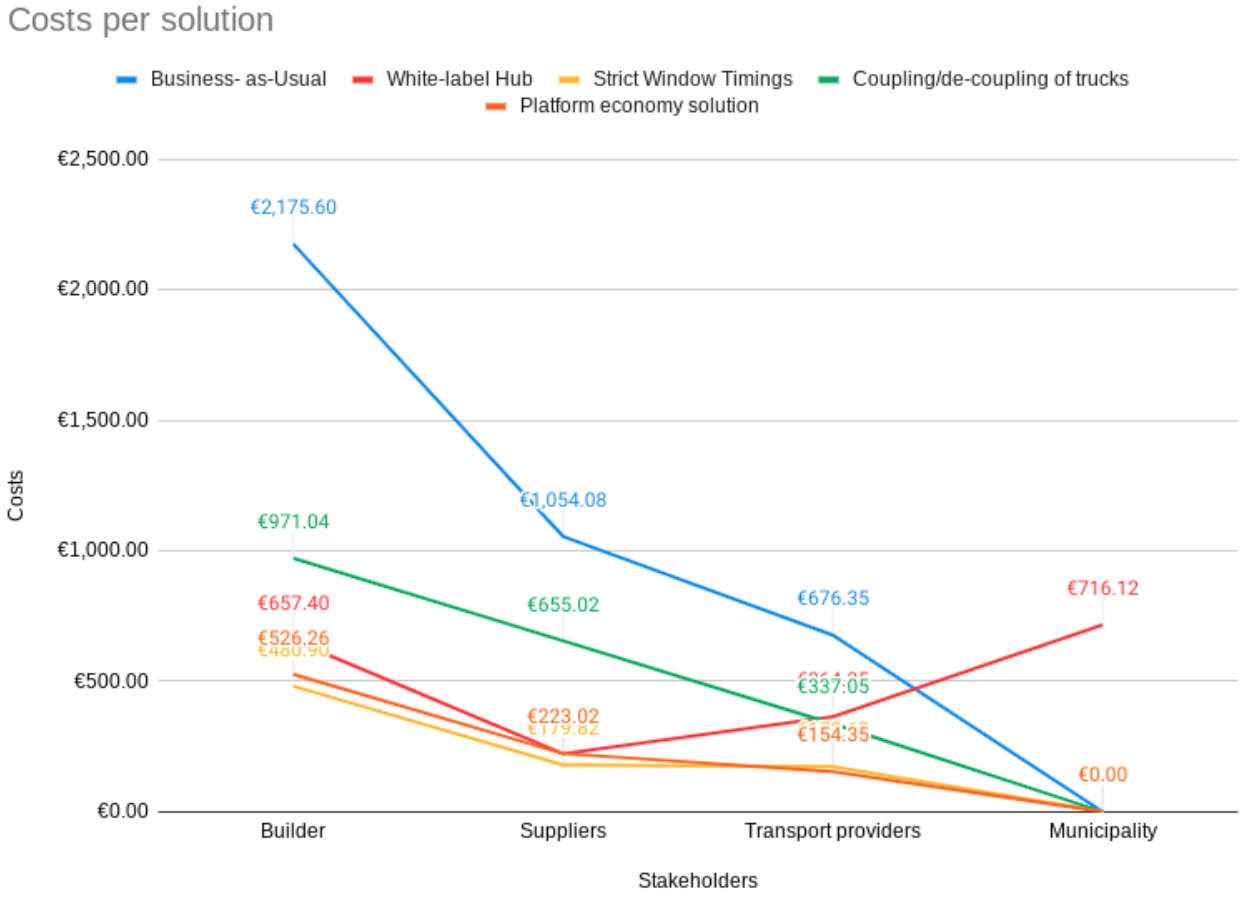

Figure A.4: Costs per solution per actor

On the right side, the quantitative costs incurred for each actor for the particular solution is

displayed as a line graph.

These parameters are indicative of the trade-offs that the parties experience in making these solutions work. Hence, these parameters and their impact need to be taken into consideration for each actor in the chain to negotiate the choice of solution by the team.

P.S. The team needs to collaboratively choose a solution based on the trade-offs of the given parameters.For this, scroll down in the sheet and select the solution the team needs to go for. ONLY ONE SOLUTION SHOULD BE SELECTED AT A TIME ELSE IT WILL DISPLAY wrong parameters in the parameter table.

4. Step 4: **Solution Organisation:** Go to TAB Solution Organisation, choose how and which party would be responsible to organise the solution for each supply flow to the construction site. Filter the solution Number indicated in cell E1. This will filter all required solution organisation possibilities for your chosen solution.

				Select the chosen solution on the indicated filter:	
Select Y/N for the Supply flow organisation	Flow	Solution Description	Actor	Solution Name	Costs of solution organisation
Y	Material	Municipality organises Hub and charges builder on pay-per-use model	Builder	White-label hub	€131.14
	Material	Municipality provides incentives for organizing hub solution (currently set at 40%)	Municipality	White-label hub	€52.46
	Material	3PL organises hub solution on vacant land nearby site	Transport providers	White-label hub	€131.14
	Equipment	Regional 3PL contact booking via FLOW 2 App	Transport providers	White-label hub	€10.00
Y	Equipment	3PL contact via email/phone	Transport providers	White-label hub	€82.11
	Personnel	E-bikes @HUB if Municipality organises the solution	Municipality	White-label hub	€59.25
Y	Personnel	Re-imburse 80% of bike use costs to subcontractors in case municipality does not organise the hub solution	Builder	White-label hub	€47.40
	Personnel	Car-pooling with tools if 3PL organises the solution	Self-organisation by subcontractor	White-label hub	€0.00
Y	Waste	Trucks carry waste downstream-Smart returns	Transport providers	White-label hub	€200.00
Y	Information Flow	Regional Logistics Manager	Municipality	White-label hub	€656.87

Figure A.5: Solution organisation interactive table

Each supply flow is indicated in a different color at the page. Indicate ¨Y¨ for EACH SUPPLY FLOW organisation you would like to take up in consideration with your teammates. DO NOT select 2 organisation ways for one Supply flow. This is NOT ALLOWED.

This step would ADD costs to responsible parties and could be observed in the right-hand side graph indicated in the sheet.The cumulative parameters in the playsession TAB may also change

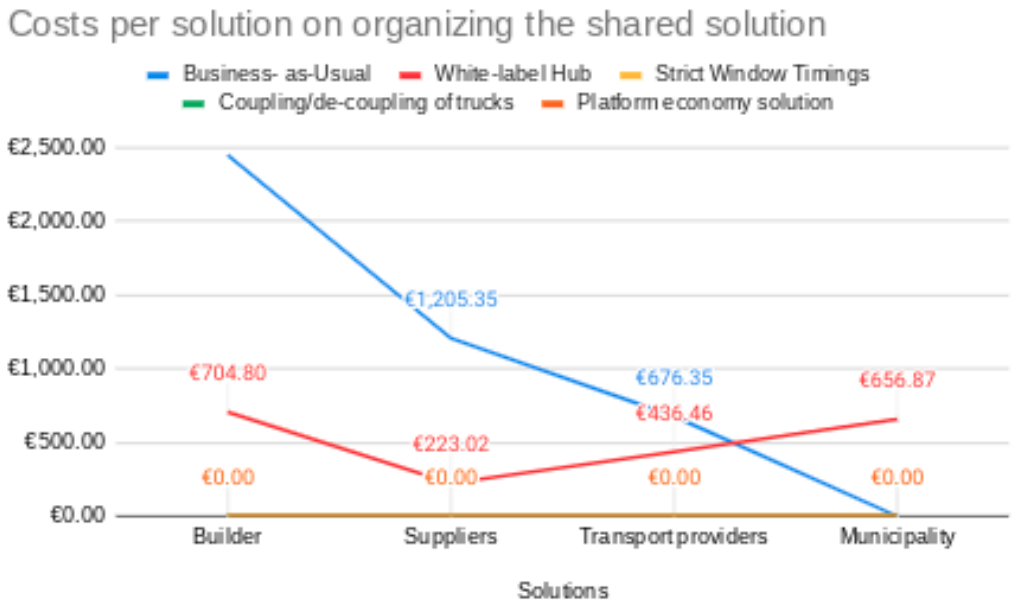

Figure A.6: Solution organisation cost comparison

based on the solution organisation choices.

P.S. Currently, ONLY one solution could be compared against the Business-as-usual solution else wrong parameters might be displayed. If you still wish to compare costs for multiple solutions, SELECT those solutions in the TAB and filter on the solution to choose organization and compare in the graph. **The above 2 steps could be conducted iteratively to arrive at the most agreeable solution.**

5. Step 5: The debriefing session would be held in the main room and the winner would be announced.
   For first play session: The team that cumulatively saves more costs would be the winner. For second play session: The team that cumulatively saves more costs and emissions would be the winner.

   Congratulations! Now you have selected the solution you want to go for. Its time to SEAL the DEAL!!! But do you think its FAIR to let one party bear the most costs?
   Lets make it lucrative for all parties so all parties would be motivated to go for the solution!
   To establish Gain-share, Go to the Cost-Share Negotiation TAB and select the option and percentage reduction of costs offered by each of your roles to achieve more balanced costs for the project.
   The Cost-share discussion would be held in the main room in presence of all players.

6. Step 6: **Cost-Share Negotiation** The cost-sharing mechanism would be mimicked as a contract signing session by the winning team presenting 3 main clauses for the contract. This session would be held in the main room so as to present a demonstration of the negotiation process to all participants.

   (a) **Clause 1**: Share the cost of organisation in the chain. The participants are presented an option of negotiating their share in organisation costs since it would serve as an incentive for the actors to adopt these sharing solutions creating a win-win situation for all.

The collaborative team would be presented with the total costs per actor & allocated costs of organisation out of those total costs for their chosen solution.

Figure A.7: Total costs for solution

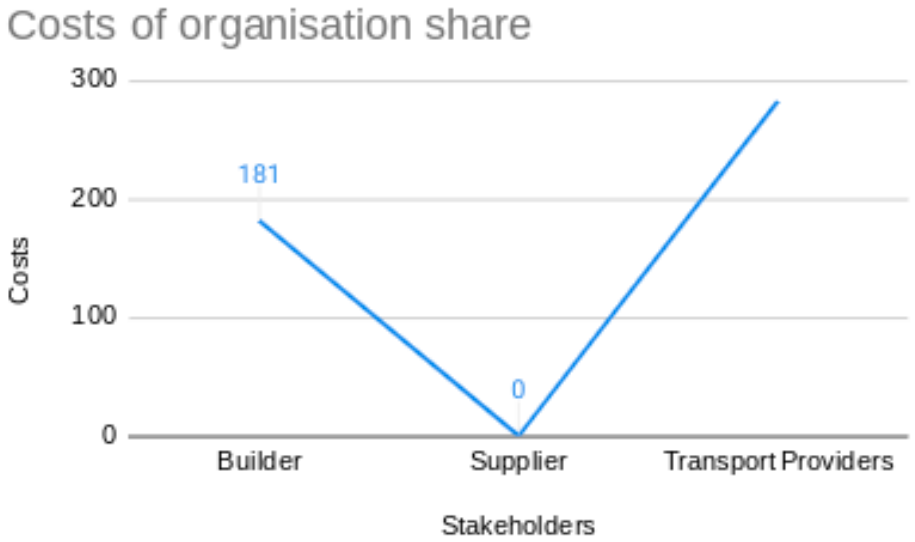

Figure A.8: Costs of organisation share per stakeholder

The allocated cost share for organisation is expressed in percentage and players are asked to negotiate the new percentage share for themselves in the chain & input in the required lines in the platform to view the impact. The organisation costs borne by municipality is not counted in the chain currently since they would be community-based costs & may not be specific for this construction case.
A feedback in terms of costs change in graph is observed when the players try reassign the percentage of cost share in the provided input boxes.

(b) **Clause 2**: If the builder tries to communicate the plan for material delivery 2-3 days before, two more negotiation parameters would come in play namely Material costs & transport costs.
Rationale: Costs charged to builder = Material costs + Transport costs
Material costs = Cost of material+ warehousing costs+ storage costs
The construction sector comprises of mostly Made-to-Stock products & given the adhoc order nature in the industry, the suppliers are required to maintain buffer stock of materials adding to storage & warehousing costs. In case of pre-order of materials by builders, these costs would be reduced at the supplier end & could act as a point of negotiation in the chain.

Similarly, better plan communication in the chain would lead to more chances of capacity sharing for the transport providers , hence reducing operational costs at their end & hence, could act as a point of negotiation offered to their clients.

But these negotiations are constraint by better plannability in the chain, and thus the input boxes could be activated only if the pre-planning option is agreed by the builder.

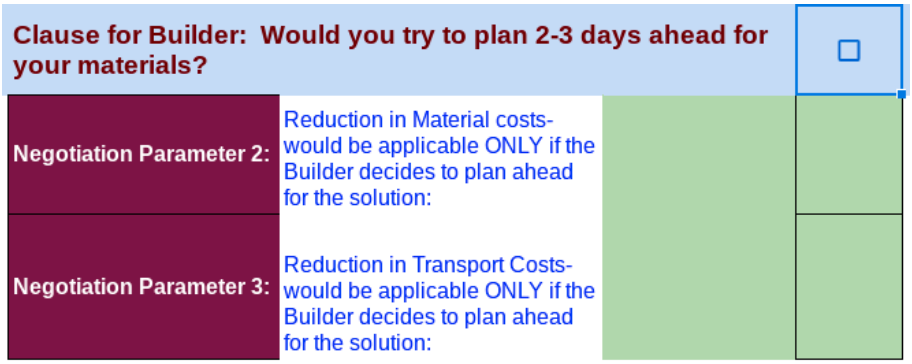

Figure A.9: Negotiation clause 2 & 3

Appendix B

Facilitator Manual

The below section depicts the step-wise approach to aid the facilitator to hold a collaborative session for raising awareness for construction logistics concepts. The actual session timing currently is set for 1 hour, however during play- tests the session have tended to prolong, and hence is recommended to be set at 1.5 hours.

B.1 Session awareness

As concluded from the evaluation session, since the play-sessions are complex to understand, it would be lucrative to send the Session Manual and a trial game link for the players to establish a pre-awareness of overall session as well as options presented in the game. The costs assumptions could also be verified by sending the section 4.4 of this report. This would help the participants to understand the maneuvers in the play-session effectively avoiding much time spent for mechanisms of the game play.

B.2 Player profile

The appropriate players for this session could either be SMEs or larger companies that serve as clients or suppliers for SME companies in the construction sector. The number of players required are 7 representing the following roles & in the first play, a suitable setup would be to have participants represent the similar roles as assigned in the play-session.

There are 2 teams that would participate in the session each comprising of 3 players of main stakeholders from the construction industry:

- 1 builder
- 1 supplier
- 1 logistics provider

These 2 teams are guided by policies provided by municipality member that would eventually set the goals of the play-session(s).

In order to evaluate the effectiveness of the session, a pre-questionnaire to measure the current level of awareness of participants is established.

Pre-questionnaire:

1. Are you aware of construction logistics solutions in the industry?
2. Have you worked on any of the projects that utilized construction logistics solutions?

The above questions would help in profiling the participants and may even lead to an interesting portfolio of participants in a team leading to lucrative decisions in the play-sessions.

Next, a pre-session brief on the motives and importance of the session need to be established in manner of a presentation. Given the complexity o the game, a small demonstration of gameplay needs to be provided in this session such that the participants are thorough with the concepts and feedback presented in the tool.

B.3 Pre-session brief

The pre-session brief to consist of a presentation depicting the overall session agenda with detailed description of storyline followed by a walk-through of the tool and the step-by-step feedback interpretation. The agenda and research basis could be facilitated via a presentation followed by an actual walk-through of the tool in the google sheets format such that the participants are aware to find the right data at the right place and possibilities facilitated by the tool.
Pre-session brief elements list:

- Session overview: Refer to figure A.1
- Session Agenda: Refer to figure A.2
- Research basis and solutions: Refer to section 4.1 and 4.4 for solutions.
- Storyline and play setting: **Storyline:**
  ¨You are tasked with constructing a hotel on the Port of Lotterdam and the project is in its Finishing phase that would take about 1 week to finish. The municipality of Lotterdam is planning certain restrictions for construction projects and a table discussion is held among the builder, suppliers and transport providers of the project to collaboratively choose a solution for organising logistics to comply with the upcoming policies. Most of the companies involved in this project are SMEs (or serve as clients/suppliers for SMEs) and are particularly worried about this since these are specialised companies and are quite wary of transparency of costs and benefits that they would achieve by adopting certain solutions.¨ The construction site has 5 supply flows coming to the site:

  1. **Material:** Palletized goods need to be collected from 2 suppliers located in the same industrial park (3 km) on tractor-trailers (max. Euro-pallet capacity: 33).
  2. **Human Resources:** 3 subcontractors need to come to the site and the reference distance point is taken as P+R (Park+ Ride) which is located about 6 km from the site.
  3. **Equipment:** Equipment is hired from a transport provider situated 4 km away from the site.
  4. **Waste collection dumper:** Construction site has accumulated waste from the activities. The waste needs to be handled.
  5. **Information:** This represents the information flow coordinated via an independent party appointed via the builder for the project or the municipality for the region.

  The session offers quick solutions targeted at sharing truck capacity to help your business better prepare for the upcoming Green Deal 2025.

  Your task is to explore the construction logistics solutions offered in the game and analyze their associated quantitative and qualitative effects and understand the negotiation or interplay you might encounter when selecting the solution.

  Prerequisite knowledge:

- Basic understanding of how the construction sector works such as characteristics of the industry, phases of construction and required supply flows to a construction site.
- Basic logistics knowledge: understanding of storage costs, transport costs, handling costs, etc.

Equipment required:

- Laptop for each player if played online.
- If played in a physical environment, laptop /computer with projector.

- Walk-through of the tool. Link of the tool could be found here.

B.4 Main Session Facilitation

B.4.1 Session setting

Assign the players to teams with respective roles to play in the session. By default, the builders would act as captain for each team and would possess the below responsibilities:

- Keep track of solutions explored in the game.
- Briefly describe the play session to the game coordinator in the de-briefing sessions.

Share the separate game versions to each team captain and provide EDITING access.

B.4.2 Play-session 1

The play-session 1 is a tutorial for the upcoming game to the played in session 2. The current goal of the game is to save the most costs in the game and the team that does that is the winner of this mini-session.

This tutorial time could be utilized to understand if the participants have gained sufficient understanding to navigate through the tool. It is advisable to hold this session in a collaborative room and provide a walk-through of the tool if the participants struggle with it.
The following steps need to be navigated through for the tutorial: In the play sessions, in addition to the presented solutions, innovative sharing solutions could also discussed that could help in optimizing the chain.

1. Step 1: Municipality passes a policy for the play session.
2. Step 2: Session facilitator to provide the EDITING access for the game to the team leader. Teams are assigned to different Break-out rooms for the next 2 steps.
3. Step 3: **Choose Solution:** Go to TAB play session. The below decision parameters are displayed in the platform:
    - **Costs:** The costs include transport costs, storage costs, waiting time and handling costs for the material from the suppliers.
    - **Emissions:** This parameter represents cumulative emissions of CO2, NOx and PM10 emissions.
    - **Time:** This parameter represents the lead time for activities in the construction logistics such as material loading time, material unloading time, waiting time at hub, waiting time at construction site due to restricted/open space.
    - **Productivity:** Productivity at construction sites stands for acceleration in production time due to improved coordination in the construction activities and good internal logistics enabling availability of all flows at the site at the same time. Productivity is viewed as a profit field for the builders as it leads to less delay in construction project overall and low spend of construction costs leading to better margins.
    - **Flexibility:** This field could imply different meanings for different roles in the game.

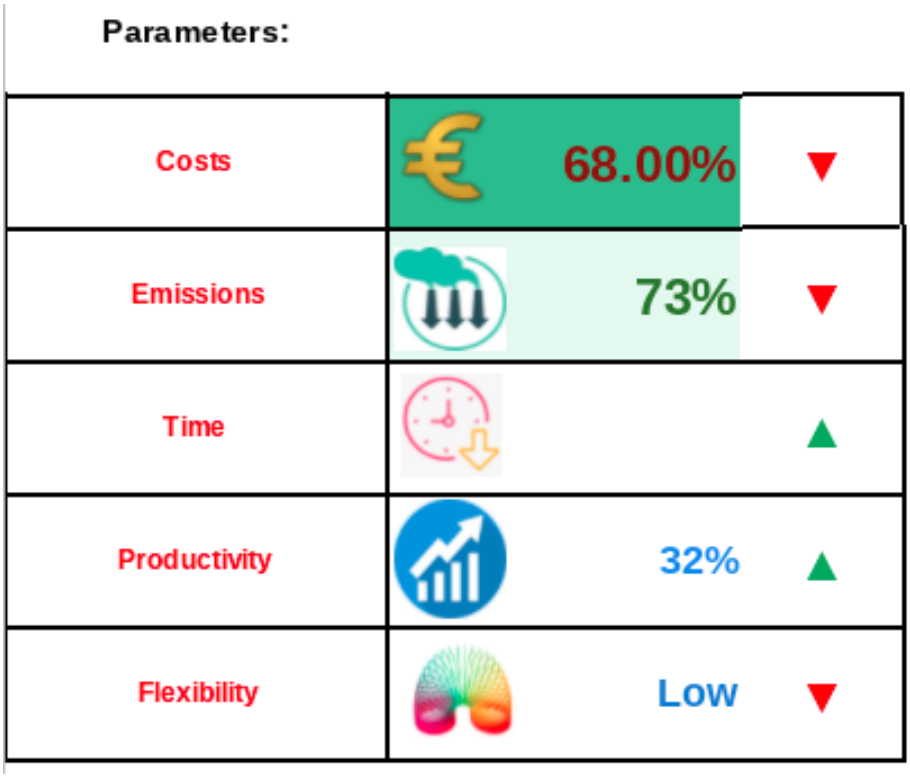

Figure B.1: Parameters in the play session

Table B.1: Flexibility parameter criteria

Role	**Implication of Flexibility field**
Builder	Builders are currently ordering the material and supplies on adhoc basis following the today for tomorrow model, but if a solution needs to be implemented successfully, a better plannability is required.
Supplier	Suppliers are specialists in their particular products and are apprehensive regarding the data-sharing with their competitors, but if a solution is required, they need to be ready to share this data amongst their competitors.
Transport Provider	Transport providers may need to share their gains with other competitors and might even face restricted movement such as regional movement in a few solutions.

The SME parties in the chain thrive on trust and good relationships with their customers wherein the builder likes to visit the supplier personally and conduct their work as well as build stronger business relationships . But this visiting frequency might reduce if they adopt the sharing solution.

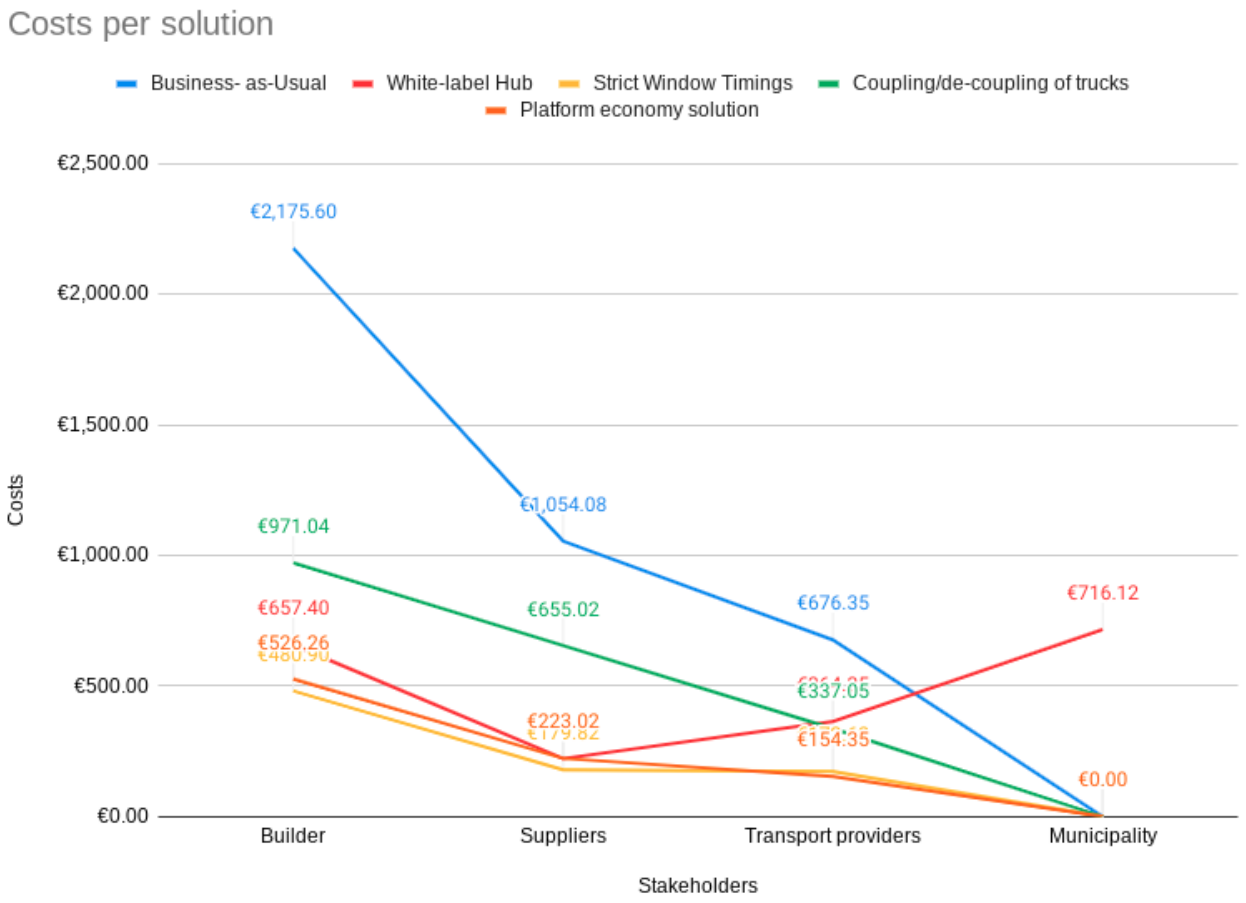

Figure B.2: Costs per solution per actor

On the right side, the quantitative costs incurred for each actor for the particular solution is displayed as a line graph.

These parameters are indicative of the trade-offs that the parties experience in making these solutions work. Hence, these parameters and their impact need to be taken into consideration for each actor in the chain to negotiate the choice of solution by the team.

P.S. The team needs to collaboratively choose a solution based on the trade-offs of the given parameters.For this, scroll down in the sheet and select the solution the team needs to go for. ONLY ONE SOLUTION SHOULD BE SELECTED AT A TIME ELSE IT WILL DISPLAY wrong parameters in the parameter table.

4. Step 4: **Solution Organisation:** Go to TAB Solution Organisation, choose how and which party would be responsible to organise the solution for each supply flow to the construction site. Filter the solution Number indicated in cell E1. This will filter all required solution organisation possibilities for your chosen solution.

   Each supply flow is indicated in a different color at the page. Indicate ¨Y¨ for EACH SUPPLY FLOW organisation you would like to take up in consideration with your teammates. DO NOT select 2 organisation ways for one Supply flow. This is NOT ALLOWED.

				Select the chosen solution on the indicated filter:	
Select Y/N for the Supply flow organisation	Flow	Solution Description	Actor	Solution Name	Costs of solution organisation
Y	Material	Municipality organises Hub and charges builder on pay-per-use model	Builder	White-label hub	€131.14
	Material	Municipality provides incentives for organizing hub solution (currently set at 40%)	Municipality	White-label hub	€52.46
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	Personnel	Car-pooling with tools if 3PL organises the solution	Self-organisation by subcontractor	White-label hub	€0.00
Y	Waste	Trucks carry waste downstream-Smart returns	Transport providers	White-label hub	€200.00
Y	Information Flow	Regional Logistics Manager	Municipality	White-label hub	€656.87

Figure B.3: Solution organisation interactive table

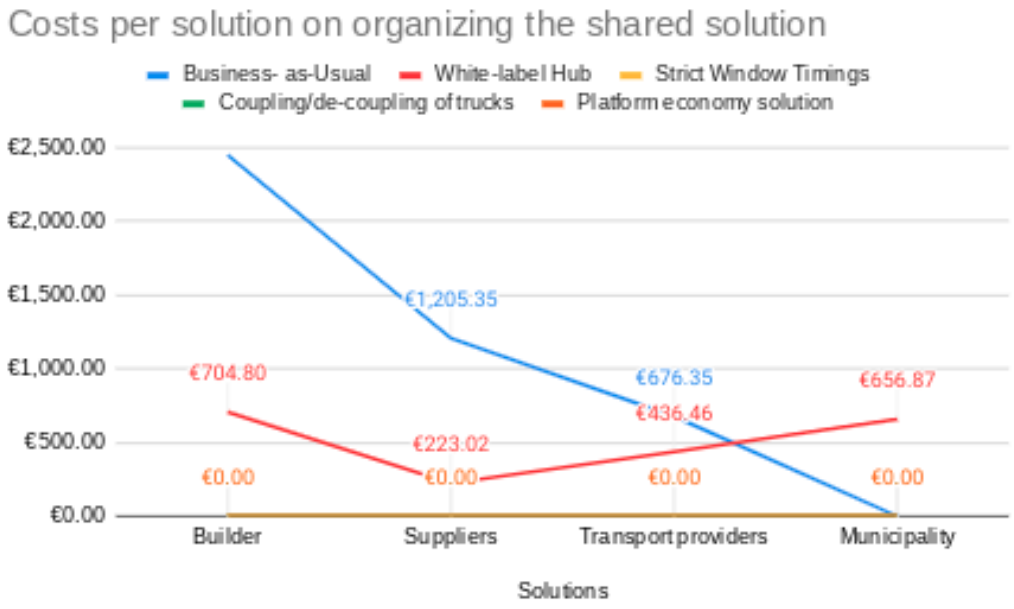

Figure B.4: Solution organisation cost comparison

This step would ADD costs to responsible parties and could be observed in the right-hand side graph indicated in the sheet.The cumulative parameters in the playsession TAB may also change based on the solution organisation choices.

P.S. Currently, ONLY one solution could be compared against the Business-as-usual solution else wrong parameters might be displayed. If you still wish to compare costs for multiple solutions, SELECT those solutions in the TAB and filter on the solution to choose organization and compare in the graph. **The above 2 steps could be conducted iteratively to arrive at the most agreeable solution.**

5. Step 5: The debriefing session would be held in the main room and the winner would be announced.
   For first play session: The team that cumulatively saves more costs would be the winner.

Also, an opportunity to share costs would be provided to the players in upcoming rounds and hence need to be communicated now such as to incentivise selection of collaborative solutions by players.

B.4.3 De-briefing session 1

Following the first play-session, the break-out rooms would be closed & the players would return to the mainroom for a collaborative de-brief session.This de-briefing is aimed to understand if the players have developed sufficient understanding for interacting with the platform and the various trade-offs presented.The below questions are part of the de-briefing:

- Do you have any doubts in the game?
- Do you understand how to navigate in the game and what kind of trade-off parameters you are presented with?

Play-session 2

After ensuring if the participants have developed sufficient understanding for interacting with the tool, the main play-session could be entered. Divide the teams into separate break-out rooms and now they need to interact with play-session 2 related TABs in the tool. An added parameter of Emissions is available in the game now. The winner needs to attain the highest save for costs and emissions for the solution:
Winning formula: Highest of Costs reduction % + Emissions reduction %
The facilitator could alternatively check with participants in each rooms if there are any doubts or help required for the gameplay.

B.4.4 De-briefing session 2

Similar to the first play-session, the players would return to the main room for collaborative de-briefing session. This session is targeted to understand the interplay of costs & other trade-offs on the choice of solutions for the players. The captain from each team would answer the below queries from the facilitator so as to stimulate a discussion and analyse different line of thoughts from the participants. The below questions would be part of the second de-briefing session:

- How did you arrive at this solution?
  - Which solutions did you explore?
  - How did you choose those solutions?
- How did the play-session go?
  - How was the discussion triggered in the game?
  - Were you able to analyse the trade-offs the decisions presented?
- Any improvement suggestions for the platform or the session ?

After the discussion, the winner for the session would be announced and a surprise cost-sharing session would be introduced by the facilitator.
The cost-sharing mechanism would be mimicked as a contract signing session by the winning team presenting 3 main clauses for the contract. This session would be held in the main room so as to present a demonstration of the negotiation process to all participants.

1. **Clause 1**: Share the cost of organisation in the chain. The participants are presented an option of negotiating their share in organisation costs since it would serve as an incentive for the actors to adopt these sharing solutions creating a win-win situation for all.

   The collaborative team would be presented with the total costs per actor & allocated costs of organisation out of those total costs for their chosen solution as depicted in figure 5.10 and figure 5.11 respectively.

   The allocated cost share for organisation is expressed in percentage and players are asked to negotiate the new percentage share for themselves in the chain & input in the required lines in the platform to view the impact. The organisation costs borne by municipality is not counted in the chain currently since they would be community-based costs & may not be specific for this construction case.
   A feedback in terms of costs change in graph is observed when the players try reassign the percentage of cost share in the provided input boxes.

Figure B.5: Total costs for solution

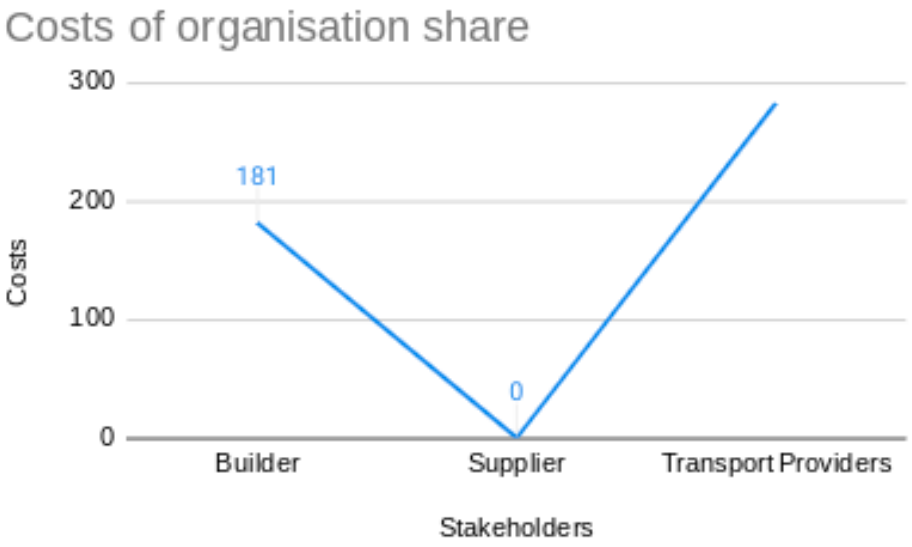

Figure B.6: Costs of organisation share per stakeholder

2. **Clause 2**: If the builder tries to communicate the plan for material delivery 2-3 days before, two more negotiation parameters would come in play namely Material costs & transport costs.

   Rationale: Costs charged to builder = Material costs + Transport costs Material costs = Cost of material+ warehousing costs+ storage costs The construction sector comprises of mostly Made-to-Stock products & given the adhoc order nature in the industry, the suppliers are required to maintain buffer stock of materials adding to storage & warehousing costs. In case of pre-order of materials by builders, these costs would be reduced at the supplier end & could act as a point of negotiation in the chain.

   Similarly, better plan communication in the chain would lead to more chances of capacity sharing for the transport providers , hence reducing operational costs at their end & hence, could act as a point of negotiation offered to their clients.

   But these negotiations are constraint by better plannability in the chain, and thus the input boxes could be activated only if the pre-planning option is agreed by the builder and shared by the parties by inputting the % cost reduction in green boxes as depicted in figure 5.12 .

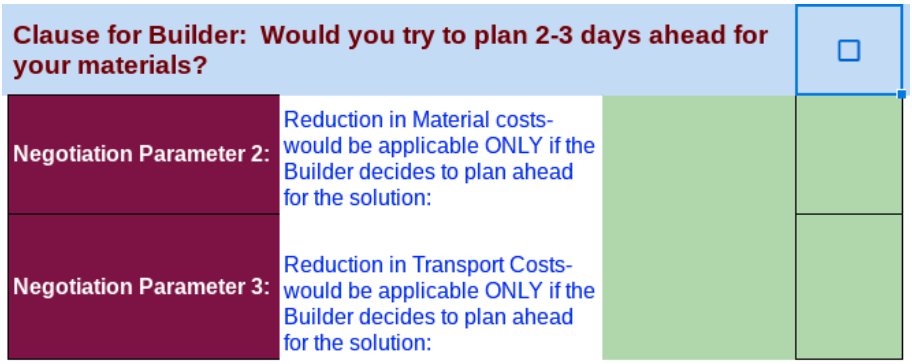

Figure B.7: Negotiation clause 2 and 3

B.4.5 Collaborative Session 3:

Creative solutions from other sectors are presented to the players to stimulate discussion & facilitate similar solutions for the construction sector as well.
Solutions from other sectors:

Zara: Establish standards for common materials manufacturing and enable bulk buying. Supplier companies could bulk buy the common material such as insulation, glass,etc. to drive down material costs.

IKEA: Kitting services could be implemented from hubs for the requirement on site.

Any creative solutions from your end?

B.4.6 Collaborative post-session brief

A collaborative de-briefing session would be held to evaluate the session impact on the players.
The following questions would be discussed:

- What was your learning from this session?
- How are game and reality connected?

- Were you able to assess the trade-offs and tensions presented in the game?
- Would you be interested to explore any of these solutions for your upcoming projects?
- Any improvement suggestions?