Addressing Challenges of Planning in Multimodal Transportation Nodes with Simulation Games

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Abstract. Global transportation knows many different modalities – goods arrive from faraway places by ship, plane, railway, or truck. Airports and seaports both represent important nodes within the global transportation network. Both show distinct characteristics, but also similarities when it comes to challenges like required flexibility, robustness, reliability and situational awareness of the stakeholders involved. In this article, we introduce two different simulation games addressing some of these challenges in two complex transportation nodes and discuss the qualitative results of user tests with the games. Within a comparative section, we show how simulation games can be used to address the challenges of multimodal transportation.

Keywords: Transportation nodes · Decision-making · Information sharing Situation awareness · Simulation game

1 Introduction

1.1 Background

Multimodal transportation nodes like the system of an airport or a container terminal within a seaport are complex and challenging environments, and play a key role in the transshipment of goods around the world (UNCTAD 2014; Saanen 2004). Planning and aligning all operations in such nodes is a difficult task. All activities are interrelated, and changes in one plan have impact on other plans.

Many actors, resources and infrastructures are involved in such complex systems. They are dynamic, huge, and show a large number of interrelations among themselves and with their environment (Von Bertalanffy 1975). Collaboration of different team members[1] in the sense of alignment of plans, and planning activities, is thus crucial for a well-functioning and performing multimodal transportation node (Meisel 2009).

[1] In the present paper the focus will not be on the differences between collaboration and cooperation as well as teams and groups. For more information see Heese (2005).

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Especially the collaboration of different team members in this field is very important. Entire systems, such as airports or seaports, would fail if individual optimization were the basis for decision-making processes. Moreover, in such complex systems, many influence factors like situational awareness (SA) of risks, emotions, communication as well as information sharing have an impact on the involved stakeholders' decision-making processes. Collaborative decision-making in the area of airport management, which includes the focus on information sharing has already shown that the punctuality of flight departures could be increased (Ball et al. 2000).

When we move outside one organization rather than focusing on the transport network as a whole, the single authority and common frame of reference are lacking, and SA has to be distributed amongst different actors in the network. Boy (2013) indicates that in such complex, socio-technical and distributed settings, four concepts of information processing play a major role to accomplish distributed situational awareness (DSA): sharing, distribution, delegation, and trading. In many cases however, distribution and trading are not sufficient. In such circumstances, trade-offs have to be negotiated between the different actors, for which again information and communication are crucial.

1.2 Motivation

To understand the complexity of multimodal transportation nodes, and the possible impact of DSA and emotions on decision-making, it is first necessary to simulate decision-making processes of teams. Second, it is then possible to analyze decision-making components as well as identify aspects like SA or emotions. With the knowledge about the functionality of decision-making processes in these domains, it is not only possible to understand the system, but also to give recommendations for an improved decision-making process of teams. There are two general methods to simulate these processes. On the one hand it is possible to use conventional methods of real time simulations. A disadvantage of such simulations is the limited inclusion or even absence of individual behavior and social elements, as they are difficult to model (Barreteau 2003). Simulations also need experts to interpret the outcomes and to translate them to the decision-makers (Lee 1973, 1994). On the other hand, the simulation gaming approach is usable. With the help of simulations, a certain procedure can be validated. In contrast to this, the simulation game approach offers the possibility to illustrate complex processes like human decision-making in an abstracted reality (Kriz 2003). By doing so, simulation games can also be used for the design of complex systems. Simulation games are more intuitive and managers as well as decision-makers can understand them more easily (Zhou 2014). When real decision-makers successfully participate in simulation games, the chance is big that they learn about the system and change their mental model (Rieber 1996), leading to a different approach towards the complex system. Mental models are one of the basic cognitive structures to understand complex systems (Cannon-Bowers et al. 1993), and key in developing SA (Endsley 1995). As the focus in the present paper is on human decision-making in complex systems, the simulation game approach was used in favor of 'pure' simulation.

1.3 Structure

After discussing the use of simulation games as a design tool for complex systems, two simulation games are presented. First, the serious game D-CITE (Decisions based on Collaborative Interactions in TEams; Freese et al. 2015) will be shown. It was developed at the Institute of Flight Guidance (German Aerospace Center 2015) as a tool to analyze complex and collaborative decision-making in (airport management) teams. Second, the multiplayer yard crane scheduler game (YCS3; InThere 2015) will be presented, developed by the Delft University of Technology and InThere. Both games will be discussed and first results of user tests will be shown. In the conclusions section, the usability of simulation games as design tool for complex systems will be analyzed based on the two cases illustrated.

2 The Use of Simulation Games as Design Tool for Complex Systems

As training and learning tools, simulation games have a long tradition in education, military, and business (Sitzmann 2011). As those games show more and more emergence and receive a broader acceptance as tools, research efforts increase, too. This can be seen in e.g. in the increasing number of game-related journals and special issues.

In general, a simulation game is characterized by a number of main aspects, such as being based on roles, rules and resources (Klabbers 2006). Simulation games are designed for a certain goal or purpose, like learning and training, analysing, or raising awareness (Abt 1970). To increase the engagement of the player, the aspects of competition or challenge are a further important topic of many simulation games. Games enable an interactive way of experiencing the complexity of a real system (Kriz 2003). The game represents a safe environment, where players are aware of the fact that they have entered a game experience, which is not reality (Klabbers 2006). Moreover, a simulation is characterized by an abstracted degree of reality. This reduced complexity is necessary thereby players can learn the game in an easier way (Abt 1970).

In our research, we use simulation games to first simulate certain situations and in a second step, to identify challenges in complex systems enabling stakeholders to design new policies and strategies for complex systems. A de-briefing of the game experience is a crucial element in this process (Crookall 1992; Kriz 2003). Before we exemplify how we adopt this way of designing and using simulation games as design instruments, we provide an introduction on airport management and the need for decision-making. After this, container transportation and the need for SA within this complex system will be explained.

3 The Multiplayer Game Decisions Based on Collaborative Interactions in TEams (D-CITE)

At an airport different stakeholder groups are part of the system (e.g., airlines, airport agent, ground-handling, air traffic control). These groups aim not only for safety but an efficient and environmentally friendly mobility. Therefore, they must continuously optimize processes. One possibility of this optimization is to foster the collaboration of the different stakeholder groups including their decision-making.

With the help of a simulation game approach it is not only realizable to validate complex operational concepts in airport management, but possible to analyze human decision-making in teams.

3.1 General Information

In the following subsections the objective, the involved roles as well as the game play of the round-based multiplayer game D-CITE are presented.

General Description and Game Objective. In a first step, D-CITE was developed as a research instrument with focus on collaborative decision-making. For this reason, it is possible to simulate and moreover analyze decision-making of teams.

D-CITE is a multiplayer game for four to five players. In terms of its development as a research instrument, the role of the moderator is a central element in the game play. At the beginning of the game, the moderator sets the duration of the game by specifying a number of rounds. In general, D-CITE consists of five rounds, though it is possible to play a fewer number of rounds if needed. Thus, it is necessary to know that the complexity increases with the number of rounds. The goal of players is to manage an airport as well as to reach the highest possible numerical team-score. To achieve this, the team has the task to collect money and gain customer contentment points. The more the players share information, the easier it is to get more points. As every player has only limited knowledge about the system of the other players, it is necessary to communicate with each other during game play (Freese and Drees 2015; Freese et al. 2015).

During the game play of D-CITE, the focus is not only the goal of the whole team to achieve the highest team-score possible, but the individual score of every single player also has relevance. The players have the task to attain the highest possible economic success (Freese and Drees 2015; Freese et al. 2015).

The game also promotes competition between teams. At the end of the game, the team gets a team-score, which describes how the team works collaboratively. Thus, the team-score is put in relation to other scores within a collected range system (Freese and Drees 2015; Freese et al. 2015). To summarize D-CITE is a simulation game for the area of airport management. As one important criteria of a simulations game, in this case it was especially necessary to reduce the degree of complexity of an airport. Otherwise it would not be possible to analyze the human decision-making processes.

Roles. D-CITE is playable for four players but it is also possible to add a fifth player. In Table 1, the roles of the D-CITE players are depicted.

Table 1. Roles of D-CITE (adapted from Freese and Drees 2015).

Roles	Description
Airline yellow	Placing a certain number of airplane cards
Airline salmon	Placing a certain number of airplane cards
(Airline light blue)	(Placing a certain number of airplane cards)
Ground-Handler	Moving busses (for passengers) as well as pallet trucks (for cargo)
Airport	Opening and closing the security checks
Moderator	Supervising the game

Game Play. The game starts with an introductory stage consisting of two main elements. During the first phase, and with the help of a tutorial, the players familiarize with the game surface. The second phase is an active training scenario. Here, players learn the game interface and how they have to play the game. After completing the introduction, the actual game play of D-CITE begins.

The game play consists of two phases. The first is the planning phase. Figure 1 depicts the main element of the planning phase. The Airport Operation Plan (AOP) functions as the game board of the first phase, which is available to all players. One round consists of seven steps. This game board is divided into three main rows (blue = flight routes [Standard Arrival Routes], green = parking positions [Stands], grey = departure time [Take-Off]). The task of the players is to adapt the AOP because of the influence of critical events (e.g., a thunderstorm) (Freese and Drees 2015; Freese et al. 2015). Therefore, every player must react and change certain plans concerning the critical event(s). The focus during D-CITE should be on the collaborative decision-making process. For this reason, it is necessary to share information with the goal of achieving the highest possible team and individual score (Freese and Drees 2015; Freese et al. 2015). After the whole team finishes one round of the planning phase, the second (simulation) phase starts. the game board of the simulation phase is shown in Fig. 2.

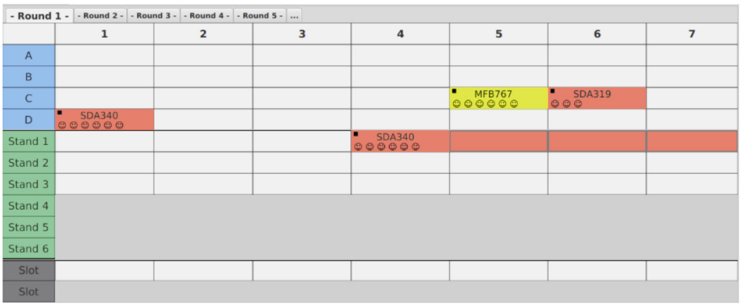

Fig. 1. Screenshot from the Airport Operation Plan (Freese and Drees 2015).

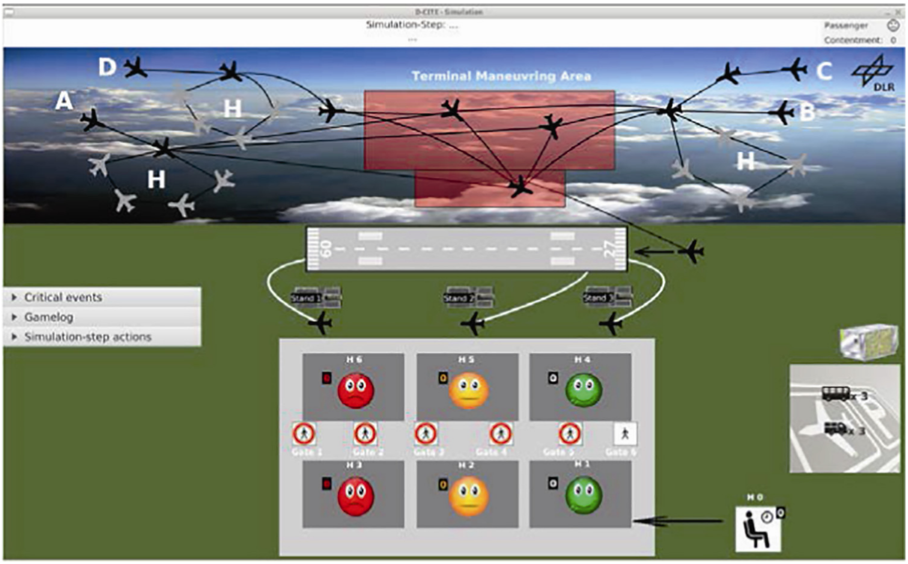

Fig. 2. Screenshot from the game board of the simulation phase (Freese and Drees 2015).

Each player has his or her own area depicted in the game board. In the upper area the airside is depicted. There are four different flight routes (Standard Arrival Routes) plus the critical zone (Terminal Maneuvering Area, [TMA]) shortly before the landing process is visible. This area is relevant for the Airline Agents. There are also three parking positions referred to as 'Stands' for the airplanes. The Ground-Handler has the task to control this area as well as the depot consisting of busses and pallet trucks on the right side. Lastly, there is a waiting hall system in the middle of the game board. This area belongs to the Airport Agent, who has the task to check the waiting halls for outgoing passengers including the security checks. During this phase, the last planning round is shown. Every token is placed automatically (Freese and Drees 2015; Freese et al. 2015).

After finishing the simulation phase, the next round of D-CITE starts. The players plan their actions for the next seven steps. After rescheduling the AOP, the simulation phase follows. At the end of the game, which is set by the moderator at the end or during the game, a result screen of all players is shown. This is based on the one hand on the money collected by each player during the game and on reported passenger satisfaction (Freese and Drees 2015; Freese et al. 2015).

3.2 Study

The study was conducted in order to determine the quality of D-CITE as a research instrument.

Participants. The sample consisted of eight airport managers (female = 1, male = 7; R = 29–52 years, M = 41.00 years, SD = 6.76 years). Two teams with four persons per team were tested. One team consists of two Airline Agents, one Airport Agent and one Ground-Handler-Agent.

Research Instruments. Several research instruments used in this study. Some of the quantitative research instruments were:

- NEO-FFI-30 (Körner et al. 2008)
- STCI-T (60) (Ruch et al. 1997)
- FIT (Mohiyeddini 2001)
- A-DMC (Bruine de Bruin et al. 2007)
- Pre- and post-questionnaire about simulation games (modified from Maij et al. 2015).

Qualitative research instruments, like video recordings of the two teams, were also used. The focus in the present section will be on the questionnaires about the simulation games.

Experimental Set-Up. In general, the experiment took four hours to complete, and progressed participants through six sections. During the briefing, a first get together was important to get to know the other players, and a questionnaire about the demographical aspects was distributed. During the first preparation phase, questionnaires concerning the topics personality and teamwork had to be filled out. In the second preparation phase, D-CITE was introduced and a power point presentation including a tutorial and training were given. Then the actual experiment then started and consisted of three rounds of D-CITE, in which the player did not know about the number of rounds beforehand. During the debriefing, the team score was analyzed and put into relation to the other scores within the collected range system. Moreover, a face-to-face interview with each player took place. In the evaluation phase, questionnaires about the perceived teamwork, workload as well as team contentment were distributed.

Results. In the following Figs. 3, 4, 5 and 6 the main results are depicted. The stakeholders gave an answer on a five-point-scale ranging from ‘applies fully’ to ‘does not apply’. On the vertical axes, the frequencies (number of stakeholders) are shown. In Fig. 3 the question was about the idea of the game. It is visible that 8 of 8 were interested in the idea.

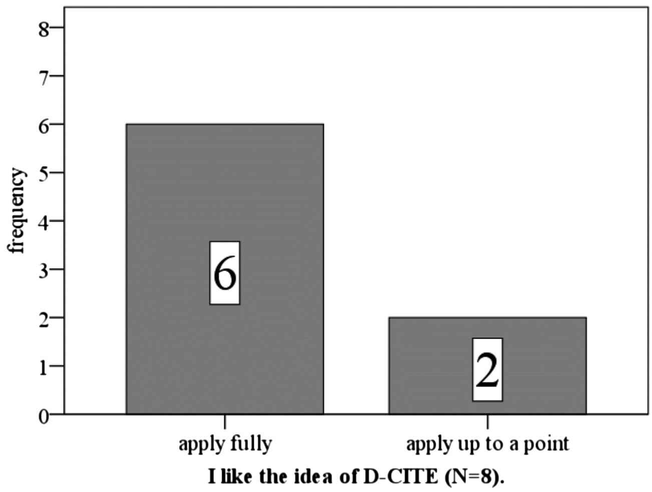

Fig. 3. Interview - idea (other categories are not depicted because they were not selected by the stakeholders).

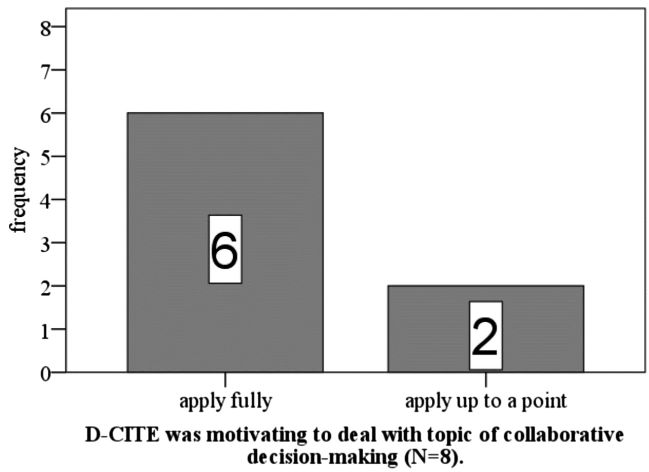

Fig. 4. Interview - motivation (other categories are not depicted because they were not selected by the stakeholders).

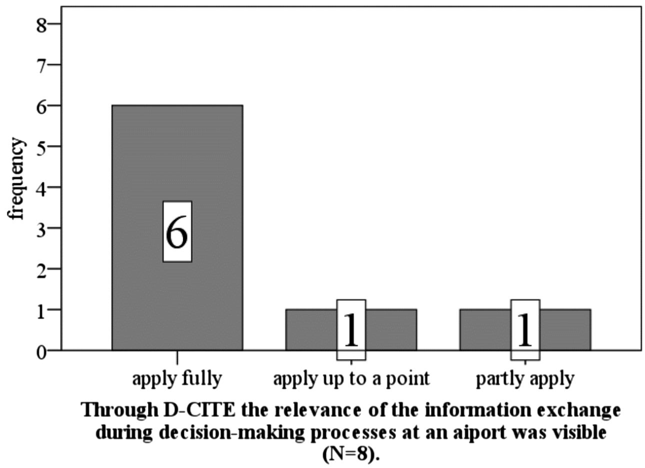

Fig. 5. Interview - awareness (the other categories are not depicted because they were not selected by the stakeholders.).

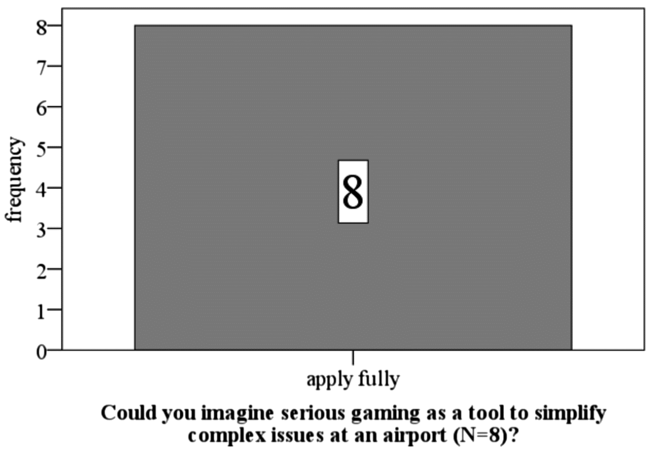

Fig. 6. Interview - tool (other categories are not depicted because they were not selected by the stakeholders).

The next question was about whether D-CITE was motivating to deal with the topic of collaborative decision-making. In this case, the results were also positive (see Fig. 4).

The question about awareness was focused in the area of collaborative decision-making. Figure 5 depicts the results. From this the relevance of information sharing in this area with a help of a simulation game was shown.

Lastly, Fig. 6 presents the results associated with the question was about the abstracted degree of reality. From this it could be seen that the stakeholders were able to image the use of simulation games in the area of airport management.

Taken together, the results show that the development of the simulation game was valued as suitable for the topic of airport management, and that the reduced degree of complexity was correct. Moreover, the results support the use of this game as a research instrument. During the experiment, the different stakeholders recommended the use of the game for research, but also conveyed its potential uses as a training instrument.

3.3 D-CITE as a Training Instrument

As already mentioned, this simulation game was designed to show the relevance of collaborative decision-making. The next step is to develop D-CITE from a research to a training instrument with focus on training the awareness about the relevance of information-sharing in the collaborative decision-making process. The general aspects of collaborative decision-making are already implemented in D-CITE (collaboration, information-sharing, feedback) (see Table 2).

Table 2. Aspects of collaborative decision-making implemented in D-CITE[a].

Aspect	Gaming components	Learning components
Collaboration	Influence of critical events	Awareness about the relevance of information-sharing during collaborative decision-making
Information sharing	Individual task menus	Limited knowledge about the systems of the other players (players have to share information to get a higher team score)
Feedback	Feedback about points/ team score	Optimize the score of the own teams, competition of different teams

[a]For more information see: Freese and Drees (2015).

It has shown to be beneficial for airport stakeholders to work collaboratively as well as to share information (Ball et al. 2000). The team members must decide which situation, including a solution, could be the best for the whole team. Therefore, criteria like a common database and feedback are considered. Players also have the possibility of communicating to each other and obtaining feedback is a further aspect of collaborative learning. This was realized in D-CITE, for instance the critical events and the consequences were shared among the players. Furthermore, another focus should be on de-briefing to analyze the game situation and the benefit for the real working environment. De-briefing is one of the most important points when using a simulation game, as it enables the players to reflect on what has happened during game play and transfer what has been earned to the real system (Crookall 2014; Kriz 2003). The concrete de-briefing of D-CITE is currently still in development.

In summary, the first evaluation shows that D-CITE is usable as a research instrument. Further experiments are planned to answer the question, whether it also works as a training instrument. In addition to this, numbers of relevant communication sequences have to be focused. In both cases, the decision-making processes are in the foreground. One most important aspect with regard to decision-making is the communication aspect. The degree of existing information has an influence on the decision-making process. As another example for this general concept the multiplayer yard crane scheduler game (YCS3) is presented next as second example of a simulation game as design tool for complex systems.

4 The Multiplayer Yard Crane Scheduler Game (YCS3)

4.1 General Information

In the following subsections the objective, the involved roles, and the game play of the multiplayer game YCS3 will be presented.

General Description and Game Objective. The multi-player Yard Crane Scheduler game or YCS3 (see Fig. 7) is a follow-up of single player game known as YCS (for details refer to Kurapati et al. 2014).

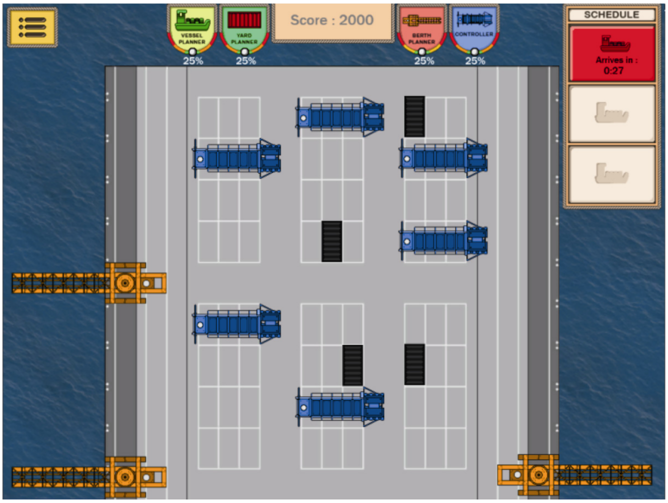

Fig. 7. Screenshot form the YCS Microgame.

The objective of either game is to manage the yard and align various planning and resource allocation activities in the container terminal. Both games have been developed to address the interrelatedness and challenges of planning tasks within a container terminal. The various planning tasks of terminal operations were handled by an individual player in YCS to understand the interdependencies among the distinct planning tasks in container terminal operations. To extend this knowledge to a more realistic setting, a multi-player version known as YCS3 was developed, where a team of 4 players need to make coordinated efforts to align all the planning tasks in the terminal. We will discuss about the roles and game play, in the following subsections.

Roles. The four roles represented in the YCS3 game are described in Table 3.

Table 3. Roles of YCS3.

Roles	Description
Vessel planner	Vessel planner's task is to plan the order in which containers are unloaded from the ship
Yard planner	Yard planner is responsible to plan the location of containers of the arriving ships in the yard
Berth planner	Berth planner has to plan and allocate the quay cranes on each ship to facilitate the unloading of the containers
Controller	Controller's task is to plan and allocate yard cranes for the containers that need to be unloaded onto their pre-allocated positions in the yard

Game Play. The multi-player Yard Crane Scheduler game is a four-player online game. It is similar to the single player YCS game in terms of layout and game play but has variations regarding roles, especially the vessel planner. Unlike YCS, the YCS3 game does not have export containers and trucks that carry yellow containers into the hinterland.

The four roles represented in the game are vessel planner (V), yard planner (Y), berth planner (B) and controller (C) as shown in the main screen of the YCS3 in Fig. 8. Each of the players choose their pre-defined roles by double clicking on their respective role alphabet, until it turns green.

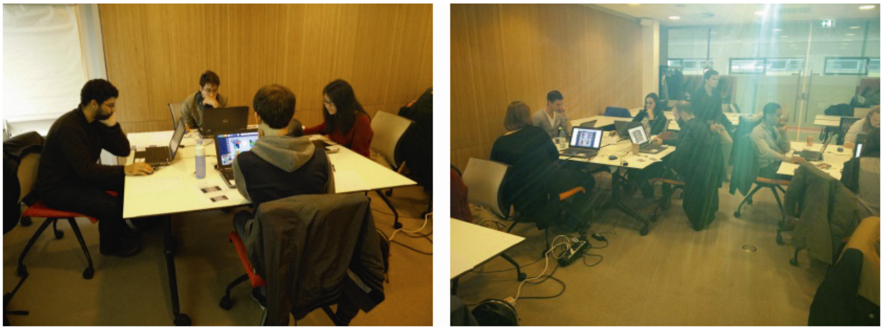

Fig. 8. Impressions of the YCS3 game play session.

In the YCS game, an individual player could view all plans and operations of all the roles, whereas in the YCS3, each role has different access to different planning and operational tasks. The berth planner can only access the quay cranes, while the controller can only access the yard cranes. The yard planner can plan the containers from the ship to the yard, and the vessel planner needs to decide in which order the containers need to be unloaded. The controller cannot allocate yard cranes if the yard planner didn't make a yard plan, and the berth planner cannot unload the ships if the vessel planner has not allocated an unloading order.

4.2 Study

The use of this game as a research and design tool is illustrated in the following subsection.

Participants. The sample population of this study was drawn from students of the Master program of Transportation, Infrastructure and Logistics at the Delft University of Technology. A total of 26 students participated in this study. Of the 26 students, 11 were female and 15 were male ($M = 23.3$; $SD = 1.7$). The majority of the participants were Dutch (20), followed by three Chinese students, and one each from Belgium, Mexico and Greece. The students received partial course credit for their participation. The researchers acted as 'guest lecturers', were not in a direct power relation with the students, and were not involved in the evaluation of students for the partial credit.

Research Instruments. The study included quantitative and qualitative research instruments. The quantitative research instruments used in this study include a pre-survey that collected the demographic information of the participant, Ten Item Personality Inventory to measure personality type (TIPI; Gosling et al. 2003); questionnaire that measured the Situation Awareness of participants (SART; Taylor 1990) and a post-game survey that measured team performance indicators (TeamSTEPPS Team Perceptions Questionnaire [T-TPQ], Battles and King 2010).

The qualitative research instruments included video recording of two teams. Although quantitative and qualitative results were produced from the study, this paper will focus on the qualitative results.

Experimental Set-Up. The research design is a quasi-experimental one, since the sample population was not randomly drawn. The experimental session began with a short briefing lecture explaining operations in container terminals and the various planning roles involved to manage these operations. All the participants are provided with laptops. They are directed to play the single player YCS game. YCS game acts as a tutorial to the players before they play YCS3, so that all the participants are on an equal footing to play YCS3. After playing YCS, participants are divided into teams of 4. There are 7 teams in total. Each team is seated around a table in a bridge game format (Fig. 8).

Participants started the experiment by answering a pre-survey that collected demographics, professional, simulation gaming experience and personality type information. Each team had to play the YCS3 game at varying levels of SA: individual SA, shared SA and distributed SA. The YCS3 game had different scenarios for the three levels of game play with the same level of complexity in order to control for learning bias. After every level of game play, the SA of the participants was measured by the SART questionnaire. The various levels of game play were as follows:

Individual Situation Awareness (SA) level of game play. In the individual SA level of the game play, all players were required to plan their activities individually with the available information, without interacting with other team members. This level of game play set the base line for team performance, based on individual decisions of the team members with no means of communication or interaction.

Shared Situation Awareness (SSA) level of game play. In the SSA level of game play, participants were provided with materials that helped them create a common operational picture of their activities. The materials include a printed A3-size sheet of the layout of the container terminal as represented in the game (except the cranes and ships), 6 conversations bubble sticky notes per player, and several colored stickers to represent containers. The sticky notes were used to pass messages between players, while all team players could view them since they were placed on the common sheet. The stickers were used to communicate regarding the container positions in the ship, and the yard. The materials provided for the players in the SSA level are shown in Fig. 9.

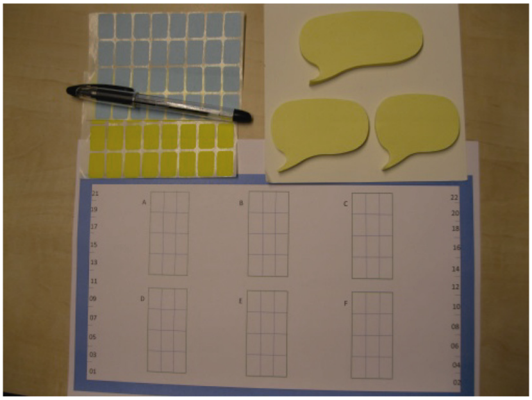

Fig. 9. The materials provided to the players during the SSA level of game play.

Distributed Situational Awareness (DSA) level of game play. Distributed SA is based on the premise that all team members need not have shared awareness of the team activity, but are able to interact with each other regarding a specific task, exchange relevant information to enable appropriate decision-making (Stanton et al. 2006). In the DSA level of the game play, the materials shown in Fig. 9 are removed. Participants were allowed to communicate with each other, without having access to a shared platform that represents their team activity.

To control for a bias related to the order in which the game was played, participants were divided them into two groups. Teams 1, 2, 3 and 4 belonged to group 1 while Teams 5, 6 and 7 belonged to group 2. Group 1 played the game in the order of individual SA, SSA and DSA level of game play. Group 2 played the game starting with individual SA, followed by DSA and finished with the SSA level of game play.

After finishing the 3 levels of the game play, participants were asked to fill in a post-game survey consisting of a SART questionnaire, as well as T-TPQ questionnaire to measure their SA as well as their perception of communication, situation monitoring and mutual support during the game play.

Results from the Qualitative Analysis. The qualitative results are based on the video recordings of the game sessions, as well as the material used in the game play such as sticky notes, stickers representing the containers and the descriptive comments of the participants on the score sheets. Three levels of game play of two teams were analyzed in order to substantiate our findings from the qualitative data. These were team 1 (group 1) and team 5 (group 2). We chose one team each from group 1 and 2, to control for the bias in the order in which both teams played the YCS3 game.

Overview of the video analysis. Analysis of videos was used to understand the differences in performance, and the factors affecting performance of one team at various levels of SA. Data were transcribed based on this research objective. Transcription can be defined as a translation or transformation of sound/image from recordings to text (Duranti 2006). The process is a selective one where only certain features of talk and interaction in the recordings are transcribed based on the research objective (Davidson 2009). Selectivity in transcription is a practical necessity because it is impossible to record all features of talk and interaction from recordings (Davidson 2009). Given the research objective, the following points for our transcription were chosen as areas of focus:

- In the individual **SA** level of game play, the players were not allowed to interact with each other. All the game related information was logged in an online database, so the transcription was limited to events where participants did not follow rules, and if the moderator has to interrupt their activity. The ethnicity, gender, and the workstation number of the participants had to be noted down. This information does not change in the next two levels.
- In the **SSA level** of the game play, participants interacted with each other using various stationary materials like stickers, notes, and so on. The transcription procedure in this level was to note down who sends information to who, where they placed the information (on the common board or to a specific recipient), and what time they performed this transaction. Interruption by the moderator, or any other event that interrupts the normal flow of the game play was also noted down.
- In the **DSA level** of the game play, players were only allowed to communicate verbally. At this level, the transcription procedure was to note down the participants involved in a conversation, direction of the flow of information (two-way discussion or negotiation, one-way direction), general topic of the conversation, and time of the beginning of the conversation. Similar to previous levels, any interruption to the game play and team activity was noted down.

Following the above guidelines, the video recordings of the 3 levels of YCS3 game play for teams 1 and 5 were transcribed. The essence of the transcription as an analysis is summarized in the following paragraphs.

Analysis of the transcription of the video recording of team 1 (group 1). Team 1 had a balanced composition of two male and two female members. All the members were from the Netherlands. The position and seating of the team members can be seen in Fig. 10.

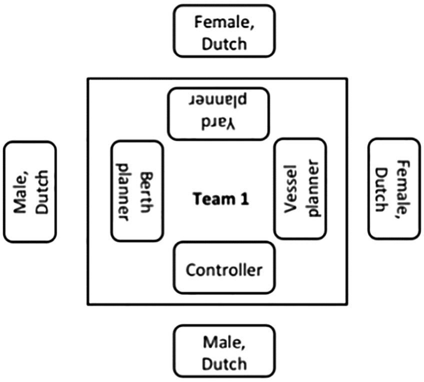

Fig. 10. Composition of team 1.

During the individual SA level of the YCS3 game play, all the members of team 1 focused on their individual task of the YCS3 game on their computer screens. At two instances, the moderator had to remind the team not to talk, as it was not allowed in the individual SA level of the game play. The team score at this level was 5586.

The second round represented the **SSA level** of the YCS3 game play, where players of team 1 wrote down messages on the sticky notes provided to them and passed on to their team members. The flow of messages was predominantly between the berth planner (B) and vessel planner (V) as well between controller (C) and yard planner (Y). The majority of the messages were from the vessel planner aimed at the berth planner. The only instance of message exchange was from the controller to the yard planner. Although the messages were aimed at single recipient, some of the notes were placed in the middle of the table on the common A3 sheet. The team players were often curious to look at the shared messages. The team score at SSA level was 5755.

In the **DSA level** of the YCS3 game play, the players talked to each other about their plans. This was the third and last round of game play for team 1. Similar to the SSA level, the conversations were mainly between berth planner (B) and vessel planner (V) as well between controller (C) and the yard planner (Y). Between B & V, the main topic of conversation was the order of unloading of the containers. As soon as a new ship arrived, the vessel planner would plan the priority of unloading for the containers, and would recite the plan to the berth planner. The conversation between them was unidirectional during most of the game play, with the vessel planner advising the plan to berth planner. The topic of conversation between yard planner and controller was about the positioning of containers and cranes in the yard. The conversations between Y & C were less frequent than B & V. They mostly discussed about the problems they were facing rather than their plans. The team score at DSA level was 9692.

Analysis of the transcription of the video recording of team 5 (group 2). Team 5 had 3 male participants, all Dutch and one female participant from China. The set-up of the team during the game play can be viewed in Fig. 11.

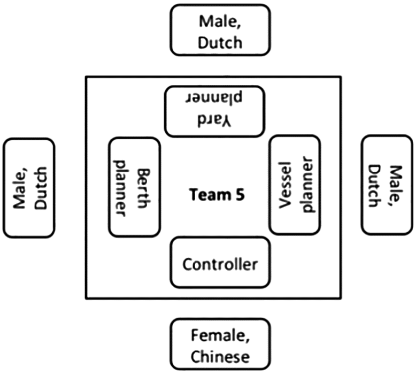

Fig. 11. Composition of team 5.

The individual SA level game of YCS3 of team 5 was very similar to that of team 1. All the team members focused on their individual tasks, with only one interruption by the moderator reminding the team not to talk. The team score at this level was 3520.

The second round of game play for team 5 was set at the DSA level. Even before the game began, the team members, particularly the yard planner negotiated game play strategies with the controller, and asked her about her preferred planning methods. During the game play, the yard planner emerged as the most pro-active team member. He constantly told his plans to the controller, as well as advised them regarding the controllers planning. The conversation between yard planner and controller was largely one directional, with the controller following the advice of the yard planner. In addition, the yard planner also asked the berth planner a couple of times to check if the berth cranes had been planned properly. The other prominent conversational pair was that of berth planner and vessel planner regarding the unloading plan of containers and position of berth cranes. Their conversation was two-directional. They mostly discussed their plans with each other, rather than follow one another's advice. The team score at the DSA level was 3067.

The third and final round of the YCS3 game play for team 5 was that of the SSA level. In this level, the yard planner passed the highest number of notes to the controller (unidirectional), and the berth planner and vessel planner equally exchanged notes. Although the SSA level had a common A3 sheet, the team members did not make use of this resource. The only shared aspect of this level for team 5, was when berth planner passed a note to vessel planner, who in turn gave it to the yard planner. The team score at SSA level was 2190.

Summary of the video analysis of teams 1 and 5. We can observe that team 1 steadily improved their scores from the individual SA (5586), SSA (5755) and DSA (9692) level of game play. The best outcome was that of the DSA level of game play. Given the time pressure of the game, which lasted only 9 min on average, the team in the SSA level could not make the best use of the stationary materials and communicate sufficiently to significantly improve their score from the individual level. However, in the DSA level, there was meaningful two-directional exchange of information between the right persons at the right time. The group consisted of 2 males and 2 female participants who all belonged to the Netherlands, which may have factored in the effective communication.

Contrasting team 5's performance with team 1, team 5 performed the best at the individual SA level of game play (3520) and did worse in the other two collaborative level: SSA level (2190), DSA level (3067). This may partly be attributed to the communication style of the team members. During the SSA level, the communication was uneven and heavily between two players (B&V). The other players did not make use of the sticky notes to communicate and share information. In the DSA level, although berth planner and vessel planner communicated, they also disagreed a lot on their joint plans, which had the effect of leading to late decision and lower scores. The yard planner was very enthusiastic and involved in a one-way conversation with the controller, who took orders from the yard planner without giving her opinion. This may also be attributed to cultural differences between the Dutch yard planner and Chinese controller. Irrespective of the order in which both teams played the YCS3 game, the DSA level scores of both teams were nevertheless higher than their SSA level scores, which might lead us to conclude that given the time pressure, sharing all the information may be less efficient than seeking information from the right person at the right time by transactions and negotiations during a complex planning process. Team composition may also play an important role in determine the performance of teams involved in complex planning processes.

5 Discussion and Conclusion

Although games have found a large distribution, and a number of different scientific disciplines research games from various perspectives, a well-grounded method in game research is still lacking (Aarseth 2003). In our research on the use of simulation games as design instruments for complex systems, we propose a contribution to the development of a method of game research with lessons learned from two case studies. We were able to draw some conclusions on the usability and usefulness of simulation games as research and design tools, following the three steps of designing simulation games for research proposed by Peters et al. (1998). First, the simulation games used in our research are developed together with experts from the field, grounded on a systematic analysis of the reference system. Second, during the design process, small steps have been taken, and all games are tested and played with the target group of the game. Third, experts validated the simulation games byplay testing and through face validity. This iterative procedure leads to a balance between realistic aspects implemented in the game and a meaningful and enjoyable playing experience. From our studies so far, we learned several important things about the use of simulation games as a research and design tool for complex systems.

When using simulation games, it is necessary to have test rounds with smaller groups before serious collection of data starts in order to be aware of risks, challenges, and problems to solve. A well-prepared script including all tasks and roles of the research team is very helpful for everyone involved and decreases the risk of failure during the collection phase of valuable data, which may be difficult to repeat.

Low-fidelity, paper-based simulation games as well as first digital prototypes allow insights in the actions and decision-making processes during a highly dynamic game situation. This set-up requires experienced observers, and a group of available researchers and/or instruments such as audio and video recorders to allow for objective observation. Computer based simulation games provide the opportunity to collect digital data instantly. This data can be used for player feedback within a de-briefing, but especially for research purposes.

The two games illustrated here show that a multi-player set-up can support the design of complex systems, as it enables the players to develop an understanding of the situation directly, and an awareness for its complexity as background for decision-making processes. The round-based game play enables players to think about their actions and decisions and decide on what to communicate to other players. In this way, both games show a certain level of reality in which actions and decisions of stakeholders are also dependent on each other and happen in a certain sequence.

Both games also demonstrated that it is rather important to decide on which information is necessary for other actors involved in the complex systems than to pass over all information available. They also show that this is the very first decision one actor in a complex system has to take, and that prioritizing of information can be a challenge. Players also have to decide who is the right receiver of the right information, especially as when disruptions of a ‘normal’ situation occur and stress levels increase, it can become a challenge. Both games illustrate how useful simulation games can be to make people aware of such challenges of complex systems, which could lead to adapted behavior in the real system, contributing complex systems design through new ways of decision making.

How these look for our research and what our conclusions are, will be the focus of our future research. This will also include the development of a systematic design and implementation concept towards simulation games as research tools.

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