Chapter X

A Simulation Game for Anticipatory Scheduling of Synchromodal Transport

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Abstract. In this paper, we explore the use of serious gaming to raise awareness about some of the trade-offs in anticipatory scheduling of synchromodal transport and to educate on how to optimize these trade-offs. We design and implement a game, called *Trucks & Barges*, which simulates a logistics service provider that needs to assign containers to barges and trucks on a daily basis. The game consists of various types of game modes in which the player can either manually plan the containers or use advanced decision support. The game includes a leader-board such that players can compete against each other. We discuss how active learning by means of the game facilitates the adoption of an anticipatory perspective when scheduling synchromodal transport operations.

Keywords. Simulation games, anticipatory scheduling, synchromodal transport.

1 Introduction

Within the logistics industry, there is an increasing interest in predictive and prescriptive analytics, using the abundance of data available to improve transport planning. Techniques from Operations Research and Machine Learning offer opportunities to translate the information into decision support for human planners. In the area of intermodal transport, these trends have led to synchromodal transport. Synchromodal transport involves mode free booking (easily switching between modalities) where transport plans require a careful balance of time, cost, and service levels. A challenge for logistics service providers (LSPs) is to provide appropriate decision support and to stimulate a "mental switch" for human planners towards a synchromodal way of working and the use of decision-support. A serious game allows them to experience this and to become convinced about the advantages it may bring.

LSPs offering synchromodal transport often seek to consolidate as many containers as possible for the long haul in order to achieve economies of scale. However, consolidating many containers in a single mode (e.g., barge, train) may result in a high number of calls/stops of that mode due to different destinations of containers consolidated. The trade-off between consolidating containers versus postponing containers to form groups with similar destinations is challenging due to the random arrival of containers. In this paper, we describe a game where the player has to decide whether to assign containers to a high-capacity mode (a barge), a low-capacity mode (a truck), or to postpone their transport. The goal is to minimize the total costs over a planning horizon, where the costs of the high-capacity mode depend on the destinations visited. This problem was inspired by a Dutch LSP that transports containers between the Eastern part of the country to the Port of Rotterdam, see [1].

In the area of complex business processes, serious games have become increasingly important for training and education [2]. For example, supply-chain interactions within external and internal actors have been taught in computer simulation games such as the MIT Beer Game [3] and the Fresh Connection. However, in the area of freight transport, simulation games have not been as widely used as in the supply-chain field, even though their potential has been recognized [4]. The games that have been developed in this area are mostly used for raising awareness about the interaction among different actors in a transport system [5]. For example, games such as the Rail Cargo Challenge [6] raises awareness about the collaboration among rail operators, terminal operators, and freight forwarders. Similarly, the distributed barge planning game [7] simulates the interaction between barge and terminal operators, and the rail cargo management game [8] simulates the interaction among transporters, clients, and network managers. Games about training a single-actor are scarce and focus mostly on passenger or public transport as seen in the review of [4]. Examples of such games that are closely related to ours are SynchroMania [9], the follow-up game MasterShipper, and the Modal Manager game [10]. Our game contributes to effectively teach students and professionals new decision paradigms in a threefold manner. First, we design a game that enables the player to experience the challenges related to transport planning. Second, we enable the player to experience decision support using advanced optimization algorithms. Third, we use challenging and competitive game components [11] that enable the testing and measuring of the effectiveness of raising awareness and educating about some of the trade-offs in anticipatory freight scheduling of synchromodal transport.

In the remainder of this paper, we describe our freight transport game *Trucks & Barges*. We subsequently describe the game mechanics (Sect. 2), game scenarios (Sect. 3), verification and validation of our game (Sect. 4), possible uses of our game (Sect. 5), and end with conclusions (Sect. 6).

2 Game Mechanics

The player takes the role of an LSP planner who schedules the transport of containers from the hinterland to a deep-sea port using trucks and barges. The capacity of the barge is limited, but there is an unlimited number of trucks. Every day, the player assigns containers to the barge and trucks of that day. New containers arrive each day, and each container is characterized by its destination, release-day, and time-window length. There are three destinations, or terminals, in the deep-sea port: *red*, *green*, and *blue*. There are two types of release-day: *same-day* and *next-day*. Containers with a same-day release can be transported on the day they arrive, while those with next-day release can only be transported from the next day onwards. Time-window lengths can be one, two, or three days after the release day. Both the daily barge and the trucks take one day to bring a container to its destination, meaning that a container with a time-window of one must be transported today.

To make the gaming experience engaging and fun, we built a digital game of the aforementioned transport situation after an initial board-game prototype (see Sect. 4). The main playing screen is shown in Fig. 1 (cost information on the right is only shown when the player presses the info button). Containers are colored according to their destination and are located in one of two container yards. The container yard closest to the bottom left corner of the screen contains containers that are released for transport and the yard closest to the top right corner contains container that are to be released (i.e., can be transported from tomorrow onwards). Furthermore, containers are labeled with a white number in the middle according to their current time-window, which decreases as days pass. To schedule the transport of containers, the player can drag-and-drop containers from the left container yard into the barge or a truck. The player can also drag-and-drop containers out of the barge, or the trucks, back into the left container yard. The daily plan is finalized and executed when the end button is pressed or when the maximum time for a day's decision has elapsed, which is indicated by the red progress bar at the top of the screen.

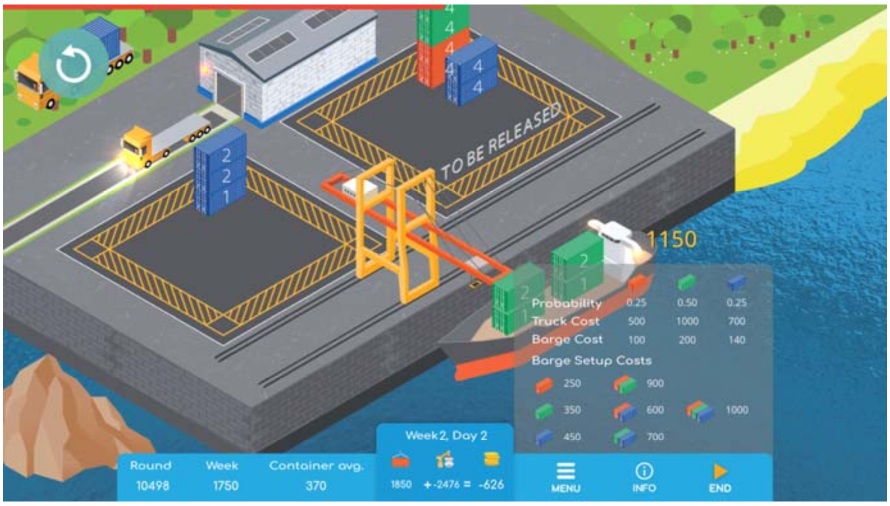

Fig 1. Main playing screen of the game.

The game is played in turns. Each turn corresponds to a day within a working week of five days. In each turn, the player has three possible decisions for each container in the yard of released containers: (i) transport by barge today, (ii) transport by truck today, or (iii) postpone its transport to a future day. The first two options result in *immediate costs*, which are displayed next to the barge or the trucks, whereas the third option does not. However, all options also influence the decisions on future days and their costs. At the end of each turn, containers that had a time-window of one and were not transported will be automatically assigned to the trucks. Then, the barge and the trucks depart (animation), and a day report is presented to the player with the costs of his or her decisions. In the transition to the next turn, two things happen: (i) containers to be released the next-day (i.e., containers in the right yard) are moved to the left yard and (ii) new containers arrive to the two container yards. The turns continue until the end of the week, where the game "cleans" the containers that were left and assigns cleaning costs to the player. At the end of a week, the player gets a report on his or her costs for each day and the cleanup costs.

The goal of the player is to deliver all containers with the minimum total costs over all weeks. For the barge, there are two cost components: a setup cost and a variable cost. The setup cost depends on the combination of destinations visited. The variable cost depends also on the destination but is added per container consolidated in the barge. For the trucks, there is only a variable cost component that depends on the destination and is incurred per container transported. These costs are accessible by the player through the info button, as shown in Fig. 1. Besides these immediate costs, the planner also has access to estimated future costs in a special *support mode* (as opposed to the *normal mode* where this information is not shown). The estimated future costs are determined using the Approximate Dynamic Programming (ADP) algorithm from [1]. This algorithm learns the weights of a linear regression model, using features of the state as explanatory variables (e.g., number of urgent containers and number or red containers). The regression model gives an estimate of the future costs/savings resulting from a specific player's decision. These estimated costs/savings of the current decision are displayed in the center tab of the main screen, together with the immediate costs of the current decision. The sum of the two supports the player in his/her decisions.

We play the game in rounds, where a *round* consists of a pre-defined number of weeks where a player is in the same mode. In addition to the normal and support modes, we use a *practice mode* to control the learning effect present when playing the game, and with these, make better comparisons between the normal and support mode. At the end of a round, a round report is displayed. The round-report has a special indicator: the performance in the last week of that round. We believe this is a good indicator to compare players, since during the first weeks, learning effects of a new type of round may occur.

The game also has a dynamic *leader-board*, see Fig. 2, where players can see the real-time costs of all players active in the session. For all players, the average costs per container in the current and best round so far are shown, together with the progress of the player. For the top 3 players, graphs with the average costs per container per day are shown. A final top 3 of players that completely finished the game is shown in the bottom right corner. Before starting a game session, players have to enter a nickname and room-key that determines the web-based leader-board where costs will be posted to. The *room-key* is a unique identifier for a game session defined by the game master. All costs and decisions, per player and per room-key, are stored centrally, in a web server.

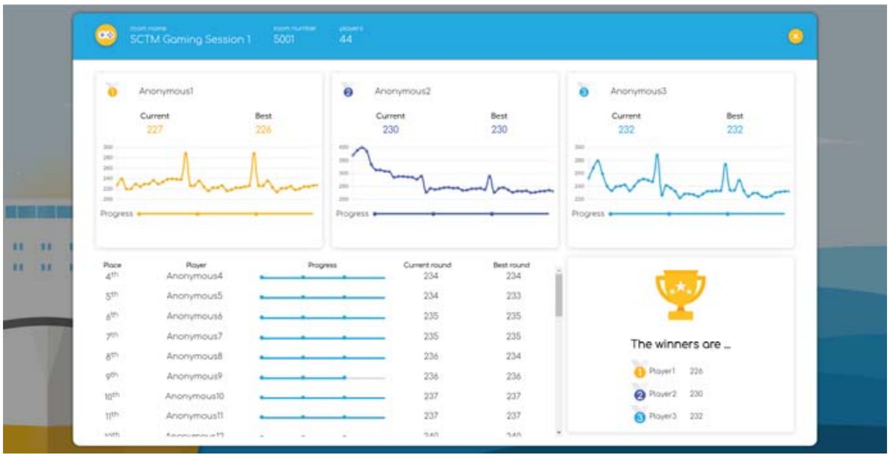

Fig. 2. Leader-board showing the performance of all players within a given game room.

The game can be seen as a single-player game with competition elements, i.e., a player's decisions with corresponding results do not depend on other players, but to boost competitiveness, players do receive live updates of the other players within the same session through the dynamic leader-board. Hence, the game can be played by any number of players. The playing time depends on the time limit for the daily decision, which is typically 30-60 seconds. Hence, the duration for a typical gaming session with two game scenarios, each having three rounds of three weeks, is 45-90 minutes. The game has a web-based version that supports the use of different devices (e.g., laptop, tablet, etc.) and platforms.

3 Game Scenarios

For the objective of the game, we distinguish between the players and the game master. For the players, the objective is to educate them on (i) intermodal planning problems, (ii) the benefits and challenges in anticipatory scheduling, and (iii) the benefits of decision support. For the game master, the objective is to enable him/her to study the behavior of participants, their awareness about the trade-offs in anticipatory scheduling, their learning process, and the way they respond to various forms/sources of decision support.

To achieve these objectives, the game master can define the following settings: (i) the sequence of different round types to be played, (ii) the number of weeks per round, (iii) the randomization setting, (iv) lists with initial states and orders, (v) costs structure, (vi) barge capacity, and (vii) basis function weights for advanced decision support. The order list determines the scheduling situations that the player will face, such as a large number of different containers most of the days or a small number of predictable containers every day. The state list determines the containers that the player encounters at the beginning of each week. The randomization settings describe whether initial states and orders are randomly selected from the lists, or are pre-determined by the game master. Using these settings, the game master can represent a large number of LSP characteristics and influence the trade-offs a players faces with respect to postponement, consolidation, and mode choice. Hence, the flexibility in game scenarios allows the game master to decide on which aspects/benefits of anticipatory scheduling to educate on.

4 Verification and Validation

Before the implementation of our ideas in a web-based game, we developed a board-game prototype of our design. Several tests were carried out with colleagues and students, and several adaptations were made. In the board-game version, the game master had to manually move out containers that were transported, enter decisions in a spreadsheet model to compute costs, and add new containers for the next day. In the digital version, all of these steps are carried out by the game code. For verifying that the game code worked as expected, we performed three types of tests. First, we created a spreadsheet model of the game and compared the outcomes of the game with those of the spreadsheet model. Second, we played the game using extreme scenarios (e.g., many containers) and with unorthodox scheduling decisions. Third, we compared to results of players with those of heuristic policies and the ADP policy from [1].

Naturally, these steps revealed bugs and glitches in the game. Together with the game programmers[1], we iterated over these steps until a satisfactory game version was achieved. For validating the game, various gaming sessions were organized with students from our educational programs as well as researchers from various Dutch universities. In these gaming sessions, we observed that the main differences among players occurred in: (i) how well they interpreted the idea of decision support (expected long-term impact of a decision), (ii) how often players consulted the costs infor-

[1] Pineapple Studios www.pineapplestudios.nl

mation, and (iii) whether players identified the differences in arrival patterns of the different container types (colors). After these validation steps, the game was ready to be deployed and is currently being used within various courses at various universities.

Lebesque et al. [6] distinguishes five key elements of an effective learning environment in the context of serious games. Our game includes each of these elements. First, *active participation* is achieved by giving the player complete control of the outcome of the game. This control plays a crucial role in the support mode, since strictly following the support might not always be the best strategy. Furthermore, the dynamic leader-board increases the involvement of a player in his or her decisions. Second, our game *challenges* the player, as game scenarios can vary with increasing difficulty, and scores of other participants as well as the performance achieved by the heuristics and the ADP policy (all shown on the leader-board) challenges players to improve themselves. Third, *interaction* is achieved through the leader-board, where players can compare their scores and discuss their strategies. Fourth, *feedback* is achieved through the day-, week-, round-, and game reports within the game as well as through the leader-board. The reports and leader-board not only show the current performance, but also the performance over time. Finally, *flow and engagement* relates to the fun side of the game; from our test sessions, we experienced that players remain enthusiastic, motivated and involved in the game.

5 Game Use

The didactic and competitive aspects make our game ideal for use in sessions with a group of players playing simultaneously and receiving feedback during, and after, the rounds are played. We discuss three possible uses of our game.

- **Pre-defined research scenarios.** Here the game master pre-defines all initial states and orders and calculates the performance that can be obtained for each round using different scheduling policies (see Sect. 4). The main purpose of such session is to study the increase in awareness or the learning of a scheduling concept. Consider a gaming session with LSP planners, where the purpose is to measure awareness of the benefits of using anticipatory scheduling support. The game master can, for example, first do a practice round with everyone and then divide the group into two parts: one playing a normal round followed by a support round, and the other playing a support round followed by a normal round. Since the game master has control over all orders, the support round can look the same for every player. In such case, the game master can measure cost differences between the normal and support mode among players with a high degree of repeatability and reliability.

- **Pre-defined competitive scenarios.** Here the game master pre-defines initial states and orders as in the previous scenario or use the randomize setting but with a known random seed, such that random initial states and orders are replicable. The main purpose of such session is to enable players to compare themselves against other players and initiate discussions among them about their performance. Consider, for example, a gaming session with logistics practitioners where the purpose is to challenge the traditional paradigm of consolidating as much freight as possible. The game master can define scenarios where sending a full barge does not lead to the optimal results. After playing a round, the game master can start the discussion by showing the leader-board and the decisions made by the best players (or the decisions proposed by the planning support) and players can share their planning paradigms.
- **Randomized scenarios.** In this type of gaming session, the randomized setting is used without a pre-defined seed value, and the presence of a game master is not required. The purpose of this type of gaming session is primarily entertainment. We created a number of pre-defined scenarios and a public version of the leader-board containing the *all-time best scores* of each pre-defined scenario.

6 Conclusions

In this paper, we designed a serious game to raise awareness about trade-offs in anticipatory scheduling of synchromodal transport and to facilitate active learning in understanding and optimizing these trade-offs. We designed the game based on a common single-trip long-haul container transport problem where containers have different destinations and time-windows. The game can be played in different modes, which help the player to minimize the logistical costs to various extents, and has several mechanisms to foster their engagement and competitiveness. The game master can define various settings of the game, which allows him or her to have different purposes for different target audiences.

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