

Ticket to Sustainability: A Board Game About Sustainable Software Engineering

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Abstract

Software becomes ever larger and more complex. The IT sector already significantly contributes to global greenhouse gas emissions, and will keep growing. As such, it is important that software developers consider environmental sustainability when creating their IT solutions. The first step towards more environmentally sustainable software is establishing awareness for the problem, as well as presenting greener solutions to developers. To this aim, we have developed an extension pack to a popular board game, Ticket to Ride, that can be used by companies and schools to teach (future) developers about environmentally sustainable practices in software engineering and prompt discussion about these topics. The extension slightly modifies some game mechanics to fit the theme, but mostly integrates a new *discussion* element - the game cards, divided in 6 categories, now contain information on sustainability issues in IT in 6 categories. Additionally, each card includes a discussion prompt that is addressed upon playing a card. Through play-testing, we found that the added extension pack blends in well with the base game and provides an enjoyable playing experience. We moreover expect the discussion element incorporated in an enjoyable game to provide a valuable learning experience. Due to time limitations, we were not able to conduct a survey and have the game play-tested by groups within our target audience. We have however provided suggestions for how the impact of the game could be validated in future research.

Keywords: sustainable software, gamification, serious games, fun stuff

1 Introduction

According to a report by Ericsson, as of 2020, ICT equipment is responsible for 1.4% of the global carbon emissions [2]. Belkhir & Elmeligi [2018] report an estimated 2.6-3.1% of global greenhouse gas (GHG) emissions as of 2018, which they predict will have increased to over 14% by 2040 [4]. Given the growth of the IT sector, it is of critical importance to make this sector more sustainable; to achieve this, we should make developers aware of the carbon footprint of their IT solutions. As such, we believe the first step to making software more environmentally sustainable is by increasing awareness of sustainability issues in software engineering and teaching good practices with regard to making software engineering more sustainable.

Another trend is the booming market for board games: in 2020 alone (during the COVID19-pandemic) the global

market increased by 20% [1]. As such, board games may also provide a good starting point for having people interact with more serious topics. To this aim, we have developed a board game extension centered around sustainable software engineering practices, in order to let developers interact with these concepts in an engaging way. Most of all, we aim for it to foster discussion on the topics addressed by the game, and establish within the developers an overall awareness of and willingness to critically think about sustainability issues pertaining to their software. We believe playing a serious game and fostering discussion in this way can appeal to our audience in ways that simply lecturing them about good software engineering practices cannot.

The target audience includes software engineers working in companies, whom are relatively unfamiliar with the concept of sustainable software engineering, regardless of their overall experience in software engineering. It would be equally suitable for (senior) computer science students, as long as they have a basic familiarity with the IT concepts that are being used (e.g. design patterns). It is ideal to play this game in groups of four (minimum two), to get the most out of the discussion element of the game.

2 Background (Sara)

2.1 Terminology

- Game-Based Learning (GBL)
- Serious Games (SG) are defined as games that educate, train, and inform [15]
- Games With A Purpose (GWAP)

2.2 Gaming theory

2.2.1 Low-touch and low-fidelity.

- low-touch approach, appeal to think differently (or even think about it at all) [17]
- low-fidelity prototyping (looks do matter) [17]
 - Evaluating general idea design
 - Quickly made
 - Can be made in early stage of the project
 - Stimulate exploration
 - Invite modifications

2.2.2 Game elements/mechanics that we used from [?] Will focus on our expansion pack, not the original game.

- abstraction
- goals and rules
 - goals add purpose

- player autonomy (by giving them option which card to discuss)
- autonomy is good for intrinsic motivation
- motivation by cooperation, recognition (by having your contribution deemed important enough to get a token even though it might not have been your turn).
- reward structures, tokens
- aesthetics, design is important
- replay or do over, maybe first round you don't know good answer to discussion prompt but next time you play you do

2.2.3 Theories behind gamification.

- - taxonomy of intrinsic motivation [10] - challenge, feedback (by other players in form of awarded tokens)
- control, choose the card that you like - distributed practice - you can replay the game - on effectiveness [16] - low-fidelity was also useful (which is our suggestion, since people will print their own sets) - Games and interactive simulation were more dominant for cognitive gain outcomes and attitudes towards the learning subject
- theories behind gamification - - taxonomy of intrinsic motivation [10] - challenge, feedback (by other players in form of awarded tokens) - control, choose the card that you like - distributed practice - you can replay the game - on effectiveness [16] - low-fidelity was also useful (which is our suggestion, since people will print their own sets) - Games and interactive simulation were more dominant for cognitive gain outcomes and attitudes towards the learning subject

2.3 Serious Gaming

[14], foundations of game based learning, highlights the importance of complete understanding of the concepts, both that you want to teach and game design. For the latter we are relying on the existing game basically. Does highlight that gamification has great potential for increasing engagement which is exactly what we want to do with our game.

2.4 Related research

2.4.1 General.

- [3] presents a game that teaches programmers about the development process. They use a game to teach this process for several reasons, one of which is the increased collaboration of games. Overall the authors got promising results and see value in gamifying the learning process.
- [8] points out that abstracting away some of the more real world elements can help focus the players on the task to be taught, software-refactoring in this case
- [9] a literature review on serious games, found that over 90% of software education games are digital. The authors highlight that most of these games focused on teaching very practical/applied software skills, while

we want to focus more on a mindset change. This provides argumentation for why our game is offline, since it is more about discussion and interaction. The paper also mentions that educational games can make it easier to "involve social aspects", which is in line with our own goals. Furthermore, the authors highlight that there is evidence gamification can make the learning process more effective and enjoyable. It is noted in this paper that gamification is hard to formalize; there is not set of rules that you can follow to create a successful game. We have the advantage of extending an existing well-known game well-liked game so we have less to worried about in this regard.

- IT Start Up¹ started on Kickstarter (they provide a printable version for free as well²). This game lays out an approach that we could take as well, provide a printable version online and maybe produce a kickstarter funded printed version if the game catches on.
- PlayScrum [7] is a card game to teach students about the Scrum agile method. Another example of a game teaching software practices using a physical card game, and again the researchers are quite positive about the results and feedback. And once again the advantage of face-to-face interactions is highlighted.

2.4.2 Sustainability focused games.

- [11] is about "facilitating a systems thinking approach to learning recycling processes and green chemistry in accordance with the United Nations Sustainable Development Goals". The authors highlight that the game can serve as a starting off-point for further teaching. It introduces concepts and encourages the players to engage with the topics. This is similar to our game design approach. The paper does acknowledge that more experienced students did not benefit as much from the game. This gives further credence to our proposal that the game should be played by people who are not already taking sustainability into account while working in the computer science field. Instead, we want to use the game to introduce people that have not yet had much experience with it to sustainability practices.
- [5] presents a game to teach students about UN sustainability goals. The authors highlight how games are great ways to introduce people to new topics, because of the collaboration often present in games.
- [15] tries to formalize game mechanics in serious games. The authors also highlight that GBL works well for teaching soft skills to players. "Additionally, the literature review indicates that there is a complete lack of studies in integrating social and environmental sustainability into serious games." Which shows that our

¹<https://shop.playitstartup.com/>

²https://www.reddit.com/r/boardgames/comments/gml5zd/card_game_about_programmersit_free_print_play_it/, last accessed on: 13-04-2023

game could be a nice addition to the current research base.

3 The Game

Creating a fun and engaging, yet simple game from scratch is a long process, so we base our game off the existing game *Ticket to Ride: San Francisco*. Because we want our game to facilitate casual discussion, the game must have a short play-time to not become tedious. The game should also be easy to learn so that players can focus on the topic of sustainability issues in software engineering, rather than game rules. *Ticket to Ride: San Francisco* fits all these requirements, as it boasts "3 minutes to learn, 15 minutes to play" [6]. The *Ticket to Ride* series already contains >20 variations on the same base game with their own map and theme [13], so it feels appropriate to extend the game once more. The game also fits thematically with software engineering. In the original game, players score points for building railroad tracks³. The process of building railroad tracks is comparable to that of building software products. A railroad network consists of interconnected stations, just like larger software products consists of smaller interconnected components. And just like there are multiple ways to connect two stations with railroad tracks, there are multiple ways to integrate two features of your software. In the future, a fully software-themed map with game pieces is therefore possible. However, due to resource constraints the current version of our game is directly built upon *Ticket to Ride: San Francisco* and reuses some of its game assets (the board and game pieces). Our game therefore functions as a prototype of an expansion pack to *Ticket to Ride: San Francisco*, rather than a stand-alone game.

The following sections first summarizes the rules of the base game, then explains how our expansion changes the base rules through the replacement and addition of certain game assets and game mechanics. Finally, we explain why we decided to make these specific changes to the base game.

3.1 The base game

This section will not explain all the rules for *Ticket to Ride: San Francisco*, but give an overview of the basics necessary to understand the game. The exact rules required to play the game can be downloaded from the official website [12].

The objective of the game is simple: the player with the most points at the end wins. Points are earned in three ways: by claiming Routes, by collecting unique Tourist Tokens, and by completing Destination Tickets.

At the beginning of the game, each player picks a colored set of Cable Cars. Each player is also given a set of Transportation Cards and Destination Tickets. Transportation Cards are used to claim Routes, while Destination Tickets show

³*Ticket to Ride: San Francisco* is already a smaller variant of the original game and changes the theme slightly: trains are replaced by the famous cable cars of San Francisco.

Original	Our game	Type of Change
Transportation Cards	Sustainability Cards (Clean and Dirty types)	Asset Replacement
Tourist Tokens	Green Foundation Tokens	Asset Replacement
-	Sustainability Tokens	Asset Addition
-	Discussion Mechanic	Mechanic Addition
-	Earning/Spending of the new tokens	Mechanic Addition

Table 1. List of the changes we made to the original game.

two destinations that should be connected by Routes. Tourist Tokens with the same logo are placed in stacks on the Tourist Locations on the board, and the game may begin.

On each turn, players may only do one of the following actions: draw Transportation Cards, draw Destination Tickets, or claim a Route. To claim a Route, the player must play the specified amount of Transportation Cards of the same color as the Route. The player's Cable Cars are then placed on the Route to mark it as claimed.

The game ends when a player has less than three Cable Cars remaining. To determine the winner, the points for each player are tallied. Points are given for each claimed Route, each completed Destination Ticket, and each unique Tourist Token collected. Points are deducted for each failed Destination Ticket in the player's possession.

3.2 Changes our game makes to the base game

The majority of the game rules overlap with the game rules from the previous section, so this section will only discuss what we have changed from the base game. The complete list of rules required to play our game can be found in appendix A.

Our game adds one new game asset and replaces two of the original game assets, which can be downloaded from our repository⁴. The most important asset is the Sustainability Cards, as they contain information on sustainability issues in software engineering. Of course, we do not want the players to feel like they are simply playing *Ticket to Ride: San Francisco* with different playing cards and tokens, we want them to actually engage with the new game assets to better internalize sustainable software engineering issues. We therefore also added new game mechanics that work with the new assets. Table 1 gives a full overview of the changes. The rest of this section explains each asset and mechanic in more detail, and justifies why we implemented these specific designs.

⁴<https://github.com/OttoKaaij/Ticket-To-Sustainability/>

Sustainability Cards directly replaces the Transportation Cards in the base game. There are TODONumber cards in total: TODONumber colors and TODONumber cards per color. The colors are separated into Dirty and Clean cards, where each color corresponds to a category relevant to software engineering. Clean cards include: mobile (TODOcolor), data centers (TODOcolor), artificial intelligence (TODOcolor), and general software design patterns (TODOcolors). These contain good practices that can be used to reduce the energy consumption or carbon footprint of software. Similarly, Dirty Cards (TODOcolors) contain bad practices or interesting facts that put into perspective how bad the energy consumption of software can be. Routes built by Clean Cards then become Clean Routes, whereas Routes built by Dirty Cards become Dirty Routes. Each Clean Card comes with a Discussion Prompt tailored to the contents on the card.

Green Foundation Tokens directly replaces the Tourist Tokens. These tokens are placed on specific Green Foundation Locations on the map. If the player arrives at one of these locations, they will be rewarded for their sustainable efforts by the Green Foundation if they have built more Clean Routes than Dirty Routes.

Sustainability Tokens are new tokens meant to parallel the use of carbon credits in the real world. These tokens are awarded for being sustainable: building Clean Routes and for participating in Discussions. To build a Dirty Route, players must pay one token. Players must therefore carefully plan their use of Dirty Routes, which may sometimes be the shortest path or unavoidable altogether. The tokens are converted to points at the end of the game, emulating the fact that the impact of sustainable solutions are usually not immediately profitable or apparent.

Discussion Mechanic. To build a Clean Route, the player must initiate a discussion using a Discussion Prompt. This is to ensure that the players actually read, discuss, and internalize the information provided on the Clean Cards. Dirty Cards do not have Discussion Prompts to emulate the feeling that dirty solutions may be quick and easy, while sustainable solutions often require more effort.

3.3 Justification of design decisions

Our design decisions were guided by the following main goal: to raise awareness of sustainable software engineering issues in an engaging, fun way. To raise awareness, we must inform. We therefore created the Sustainability Cards, which replaces the Transportation Cards. The Sustainability Cards provide information regarding sustainable software engineering issues, and is the main method of raising awareness among the players.

The original Transportation Cards, however, have no information on them as only their color matters for gameplay. Players could therefore choose to ignore the information on the Sustainability Cards, and end up learning nothing about sustainable software engineering. Furthermore, pausing the

game to read the cards may feel stressful and disconnected from the rest of the game. The game therefore needed a mechanic that forces players to read and digest the information on the cards. To solve this problem, we added Discussion Prompts to the Sustainability Cards and came up with the Discussion mechanic. The Discussion mechanic allows each player to digest the information on their card and at the same time share their findings with the group through an open discussion. The Discussion mechanic, however, brings up another problem. Discussions take time and effort, so why would players engage in it?

This leads us to the next problem: how do we make the players care about more sustainable software engineering, and care about engaging in the discussions? Translating this goal into game terms, playing sustainably and engaging in discussions should be rewarding and increase your chances of winning. We therefore introduced the Sustainability Tokens as a new asset, which are awarded for making sustainable choices and to incentivize everyone to participate in the discussions. These tokens are then translated into points at the end of the game.

Another issue we wanted to tackle is how to make the game reflective of sustainability challenges in the real world, and give the players a sense of the dilemmas that are often present in practice. Sustainable solutions are often only profitable long-term, and sometimes not viable at all. Less sustainable solutions may be quicker and cheaper to implement, and may sometimes be your only option. This is reflected back in our game where players must connect Locations by Clean or Dirty Routes. While there are several paths to the same Location, sometimes a Dirty Route will be the quickest path or the only reasonable option. Dirty Cards therefore do not have a Discussion Prompt so they are quick to play. Playing too Dirty, however, is discouraged by requiring players to pay Sustainability Tokens to claim Dirty Routes, which parallels carbon tokens in practice. Sometimes, going out of your way to be more sustainable may give you favorable public attention. We have reflected this in our game by replacing the original Tourist Tokens by Green Foundation Tokens, which can be collected from stacks situated at the edges of the map.

Fun is a quality that is difficult to measure and anticipate. We hope that by making the new assets and mechanics interconnected and reflective of real life sustainability challenges, the game will feel more fun than if we simply replaced the playing cards. To determine how fun our game really is and whether our design decisions have the impact we expected, we must perform validation testing.

4 Validation

Validation of the game is a crucial step in ensuring that the product effectively achieves its intended goals. The purpose of this validation is to confirm that the game promotes

awareness and discussion of sustainable software engineering practices among developers. Due to time constraints, no complete validation was carried out. However, we play-tested the game during development, and are confident it is a fun way to engage with sustainable software engineering ideas.

While these play-tests provide valuable insights, it is not a comprehensive assessment of the game's effectiveness and efficacy. We recognize that a proper validation of the game would involve more extensive research with a larger and more diverse group of software developers.

The play-test would be followed by a short survey (see B) designed to collect feedback on the game's ability to promote discussion, identify areas of improvement, and motivate developers to implement sustainable software engineering practices. Proper validation would also involve conducting a controlled study. The study would involve randomly dividing participants into two groups, with one group playing the game and the other not playing the game. The study would then evaluate the differences in understanding and awareness of sustainable software engineering practices between the two groups. In addition, we could create a more extensive survey, and incorporate more open interviews.

The results of this study would contribute to our understanding of the game's efficacy. By comparing the two groups, we could assess the impact of the game on sustainable software engineering practices more accurately. Additionally, a larger sample size would increase the statistical power of the study, making our conclusions more robust.

5 Discussion & Future Work (??)

Important section for grading. Should relate back to the topics from the lectures. Suggestions:

- What is the practical significance of our solution?
- What are limitations of our solution?
- Limitations of our validation method. Assessing how well a game is able to "raise awareness" is difficult to measure. Player experiences will be subjective. It would be interesting to see if introducing this game into a software company actually contributes to greener software practices, but not within our resources.
- Are there any interesting parallels between our game and real-life?
- I'm struggling to come up with stuff.
- Could relate to the paper we did our literature review on: how solving sustainability issues requires social change in the integrated approach. This game is about raising awareness in individuals, to drive them to change their perspective, i.e. social change.
- What are things we could have done (future work) to make the game more impactful? Actually getting people to play the game; would require publishing and distributing it to software companies somehow.

- Outreach: get people to actually play the game. Ship out to uni's and companies
- Validation: scientifically verify that this works.
- Content: stay up to date with current SSE research, improve literature review thoroughness. Add cards so you can play with bigger ticket to ride version etc. Expand to other games?
- Relate our game to concepts introduced in the Background? Or put this in Justification-section?

6 Conclusion (??)

Unsure if this section is necessary, it wasn't mentioned in the lecture. For such a short paper, it will be a very brief summary anyway.

7 Acknowledgements

Part of this report, specifically the section on validation, was written with help from ChatGPT, a language model developed by OpenAI. ChatGPT was used to expand bullet points into full paragraphs, as well as to rewrite existing paragraphs into a more readable style. All generated text was checked and edited to fit into the text. It is important to note that the responsibility for the content of this report lies with the human authors.

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A Game rules

The objective. Have the most points at the end of the game to win. Points are earned in three ways: 1) claiming Routes, 2) collecting Sustainability Tokens, 3) collecting unique Green Foundation Tokens, and 4) completing Destination Tickets. Points are deducted for failed Destination Tickets.

The setup. Before the first round is played, each player receives: 1) 20 Cable Cars in a color of their choosing, 2) two randomly drawn Sustainability Cards, 3) two randomly drawn Destination Tickets, of which one may be discarded. The board is then setup by placing five randomly drawn Sustainability Cards face-up, and by stacking Green Foundation Tokens of the same symbol on the Green Foundation Locations marked red on the board.

Taking turns. On a player's turn, they may do only one of the following actions:

- *Draw Sustainability Cards.* The player may draw two cards randomly from the deck or from the face-up cards. Cards taken from the face-ups, must be immediately replaced from the deck. If the player picks a wildcard from the face-ups, they may only draw once.
- *Draw two Destination Tickets.* They may discard one.
- *Claim a Route and initiate a Discussion.* Each route consists of a number of colored blocks. The player must play the same amount of Sustainability Cards in the same color as the colored blocks. To mark the Route as claimed, the player places its Cable Cars on the blocks.
 - Claiming a Clean Route initiates a Discussion. The player may choose one of the Discussion Prompts from one of their played Clean Cards. The initiating player may contribute to the Discussion first. Other players are then welcomed to contribute. The majority of the group then decides whether a contribution was positive, i.e. it provided a valid or interesting point. Each positive contributor receives one Sustainability Token.
 - If the Route connects with a Green Foundation Location, the player is rewarded one Green Foundation Token if they have claimed more Clean Routes than Dirty Routes.
 - Dirty Cards do not have Discussion Prompts, so no Discussion can be initiated when claiming Dirty Roads.
 - Claiming a Route with Dirty Cards costs one Sustainability Token, whereas using Clean Cards rewards one Sustainability Token.
 - Grey Routes can be claimed by a set of same-colored Sustainability Cards in the color of the player's choosing.
 - Wildcards can take any color.

Ending the game. When a player has less than three Cable Cars remaining, everyone gets one final turn. Points are scored for:

- *each claimed Route.* Longer routes give more points, as stated on the board.
- *each completed Destination Ticket,* as stated on the Destination Ticket. Deduct the stated points for each failed Destination Ticket.
- *each unique Green Foundation Token collected.* The more unique tokens you have the more points you get, as stated on the board.
- *each Sustainability Token,* which gives one point each.

B Evaluation Survey

- How enjoyable did you find the game? (1-5, n.a.)
- How well did the game promote discussion among the team? (1-5, n.a.)
- How well did the game help identify areas where your team could improve in terms of sustainable software engineering practices? (1-5, n.a.)
- How easy was the game to understand and play? (1-5, n.a.)
- Would you recommend the game to other software development teams? (Yes/No)
- Do you feel more motivated to implement sustainable software engineering practices after playing the game? (Yes/No)
- Do you have any suggestions for improving the game or making it more effective in promoting sustainable software engineering practices?