# Game outcomes

General outcomes plot for reference. **Attention:** always make sure to check the scales of every plot. I have not yet spent time on formatting all plots, therefore sometimes they may seem a little misleading (and inconsequent).

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|  | Legenda voor alle figure: |

### Definitions

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| (assessed player) profile score, Q-score | Player profile score for an objective, assessed through the questionnaire, also referred to as Q-score. |
| (played team) strategy score | Objective profile score determined from the actions (i.e. what project methods) taken in the game |
| (Expected) revenue | Expected revenue of doing maintenance, only includes project rewards and maintenance costs, does **not** include ttl penalty. Formula: R = W – C(regular) – 1/3\*C(delay) |
| (Expected) ttl | Expected traffic time lost due to maintenance in hours. Formula: T = TTL(regular) + 1/3\* TTL(delay) |
| (Expected) profit | The expected profit of a team/session, **including** the ttl penalty. Formula: P = R - T |
| Risk aversion | Players/teams are said to be risk averse iff they minimise the **worst-case** profit loss or ttl increase. Due to the model, this is equal to robustness in the game. |
| Max( X ), Min( X ), Avg( X ) | Maximum, minimum or average over all rounds of a team or session for the specified objective X |

# Validation

Before going into hypotheses, we first validate the model we use… blabla

## The actions (project methods) are label consistent to their intended impact on the game outcomes for all of the objectives (a) profit, (b) ttl and (c) risk aversion.

**Expectation** The method decisions made by the teams, each focused on a specific objective (revenue, TTL, risk aversion), affect the targeted objectives positively. I.e. a joint plan with a high TTL strategy score average over all teams leads to an outcome that has a comparatively low TTL.

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| 1. Revenue |  |
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| 1. Ttl |  |
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| 1. Risk aversion (worst case) |  |
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**Observation** From most of the figures we can see a clear relation between the action choices, expressed as strategy scores based on the joint plan, and the outcome. Each of the figures plots one of the strategy scores versus the outcome for one objective and each data point corresponds to a joint plan at the end of a round in a game session.

The top-left figure illustrates a tight coupling between revenue score and the obtained revenue. As the top-right figure shows, this does not directly apply to profit as well: due to the TTL penalties, there is no significant correlation between the revenue strategy score and resulting profits.

The figure in the middle row shows the relation between the strategy ttl score and the expected ttl of the joint plan. In general, the data points seem to indicate again a strong relation between the ttl score and the ttl of the joint plan, except for a few outliers. All of these outliers can be attributed to the initial planning round where players do not communicate/coordinate and are therefore to be expected to be much worse in terms of ttl.

The bottom figures show the worst-case revenue loss and worst-case ttl increase for a joint plan as a function of the risk aversion strategy score. Here once more a clear relation can be seen from the figures, i.e. a higher risk aversion score results in a lower worst-case ttl loss or ttl increase.

# Hypotheses

## Players of the game are rational agents in that they will strive to (a) optimise the trade-off between profit and TTL, and moreover will inherently (b) balance both objectives.

**Expectation** Players are inherently rational optimisers and will typically try to find plans that balance both objectives.

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**Observation** From the top figures we see that, based on the questionnaires, many of the players have assessed profile scores close to the Pareto front of optimal trade-offs (session scores are aggregated using the Borda count). Moreover, the trade-offs are made in a nearly-balanced fashion with a slight tendency towards revenues.

In-game we see a slightly different picture. The in-game strategy scores, based on their planning decisions, tend more towards profits. In particular, when the game is progressing this tendency increases. We attribute this to two reasons:

1) Although TTL is not the most prevalent choice in the plans, in most sessions the teams have realised that focussing on the ‘short-but-severe’ strategy (high TTL but only briefly) they can actually reduce the TTL due to concurrent maintenance and thereby still realise high profit and low ttl. In particular, this explains the ‘decrease’ in strategy scores between R1 and R2 for both revenue as well as ttl, as in R2 methods are chosen that indirectly cause this effect but are not primarily designed for this goal (hence the lower scores).

This is also confirmed by the ratio plots (Hyp. 2)), by for instance Eneco, where the ratio revenue/ttl increases over all rounds. Although this strategy does work in many cases, it also sometimes lead to worse TTL results, mainly as a result from ‘bad’ joint planning.

2) In the last round of the game this tendency is typically very high, because the team that has the most profit at the end of the game receives an individual price

## Players learn how to make better planning decisions during the game

**Expectation** Following hypothesis 1, we expect players to employ balanced a strategy and will try to both increase their profits as well as lower the overall TTL during the game. Intuitively, we expect that, over the course of the game, the profits will increase and TTL decrease progressively as teams will learn better how to play. To this end we define the performance ratio of a player in round as the revenue divided by the TTL: .

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**Observation** We see that in most cases indeed an improvement in performance ratio is made as rounds are progressing with the exception of the last round (because of the ‘individual profit prize’, as discussed in hyp. 1). This indicates that together the players either increase the total revenues or decrease the ttl, or both, by improving the joint plan. Furthermore, as the performance generally keeps improving until the last round, players succeed in making subsequently better decisions which suggest they learn how to control the effects of their actions. The only session in which this pattern is not directly satisfied is that of RWS (18-12). Here the players requested many intermediate scores to see the effects of their changed decisions, which were not always for the better. Nonetheless, the ‘decrease’ in performance from R4 to R5, and from R5 to R6 is both just -0.03.

In order to provide more evidence for the learning effect this we perform a paired, two-tailed t-test over the *changes* in performance ratios of subsequent rounds: and we compare pairs . We define the null hypothesis to be , i.e. difference between the samples is due to chance, and we test this with a confidence bound of 95%. This gives us a t-test score of 0.001 and therefore well within our confidence bound of 0.05, thus we reject the null-hypothesis.

## A higher level of coordination over an entire session leads to better outcomes in terms of both profits as well as TTL

**Expectation** When players coordinate their plans more, the total profit increases and the total traffic time lost decreases. More coordination leads to better awareness of decisions made by others and making decisions jointly instead of (more) individually is expected to result in better outcomes.

**Observation** A higher level of coordination does indeed improve the TTL. The profits, however, show a different pattern. Coordination appears beneficial up to the level of fully centralised planning. Based upon our observations, we reason that this is due to the TTL-focused playstyle that players exhibit when they are fully cooperative: they are willing to trade-off profits for a group-wide decrease in TTL. In the fourth coordination level, where players use representatives, they are co-operative but still represent their own profit cause.

## Social cohesion influences the outcomes of the game positively

**Expectation** We expect that players that are more familiar with each other – e.g. colleagues, friends or a student group – positively affect the outcomes of the game. The intuition here is that players are more willing to collaborate and/or sacrifice to help others.

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|  | Max  REVENUE | MAX  PROFIT | Min  TTL | REVENUE  Q-score | TTL  Q-score | REVENUE G-score | TTL  G-score |
| Unfamiliar | 51198,89 | 22356,56 | 24494,33 | 0,83 | 0,70 | 0,77 | 0,20 |
| Familiar | 47268,08 | 22095,42 | 19341,08 | 0,81 | 0,72 | 0,60 | 0,34 |
| Correlation | -0,70 | -0.061 | -0,710 | -0,253 | 0,208 | -0,844 | 0,783 |

Table 1: Averages of outcomes and profile scores per cohesion group

**Observation** The figures suggest that a higher level social cohesion has a negative effect on the maximum revenue that is obtained in a game round (col 1). For the traffic time lost (col 2), the correlation provides some evidence that social cohesion positively affects the ttl of the outcome. We venture that both these effect (both revenue and ttl decreases) can be attributed to the fact that when players are better acquainted in a session, they are more likely to strive for the joint optimisation of TTL, thereby sacrificing the ‘egoistic’ revenue aspect.

This last claim can be strengthened by comparing the profile and strategy scores of both groups. Social cohesion has little effect on the profile scores that were assessed per player beforehand. There is however a significant difference between the played strategy scores, derived from the planning decisions in the submitted joint plans *during the game*. In the ‘familiar’ group the decisions are more in favour of ttl in comparison to the ‘unfamiliar’ group (backed also by the stronger Pearson correlation).

Finally it is interesting to note that, even though familiar players are likely to obtain a low relatively low ttl in the outcome, the profits obtained in these sessions is generally lower than that achieved by unfamiliar players.