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The Road Maintenance Planning Game

Game design and first results

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Abstract

This white paper describes the Road Maintenance Planning game, a game that simulates planning, coordination and execution of maintenance projects in the domain of infrastructural maintenance. In particular, the game models the dynamic contracting procedure of Volker et al. (2014), an innovative way of contracting public works to a team group of service providers. Foremost, this paper describes the game design, its practical set-up and the methodology for collecting data from gaming sessions so that future researchers can make use of the game. Additionally, this white paper includes a complete overview of the first empirical results obtained from 7 gaming sessions as part of the research of Scharpff et al. (2019). The source code and design documents can be found on GitLab¹ and may be used for academic purposes only.

This paper is organised as follows. Chapter 1 describes the game design and setup in detail, including a level playing field game model. Chapter 2 describes the methodology to gather both qualitative as well as quantitative data regarding the decision making, performance and context of players. Chapter 3 presents the full results of 7 gaming sessions that were performed in the context of the study by Scharpff et al. (2019). Finally, Chapter 4 validates the correctness of the game design by correlating the played strategies to the outcomes, using the results of the aforementioned gaming sessions.

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1 Game Design

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¹https://gitlab.com/jscharpff/maintenance-planning-game

1 | Game Design

The Road Maintenance Planning game is designed as a level playing field so that every player faces the same set of challenges. The network that has been used in the sessions is depicted by the fully-connected pentagram of Figure 1.1, modelling a network of six fictive cities (orange) connected by a total of 45 road segments. Every player is given a maintenance portfolio consisting of four projects, corresponding to the road segments assigned through tender, that need to be serviced within the period of 1 year (assumed equal to exactly 52 weeks). The assignment of road segments to players is indicated through the colours of the segments, e.g. the red player is responsible for the maintenance of segments B12-A, B12-B, B12-C and B1-C. Furthermore, for each of these segments, the players are given four alternative ways to perform the maintenance, LOW COST, LOW TTL, NO RISK and FAST, that impact the objectives of a player in different ways. Whereas for instance the LOW COST alternative has low execution costs but a higher ttl, the NO RISK method ensures that the maintenance will not delay and thus ensuring a robust execution with predictable costs and ttl. How and when to schedule their maintenance within the 52 weeks is entirely up to the player's preference and strategy. Note that a player may also decided not to perform maintenance of a segment, at a penalty of 1/3 times its agreed price upon completion. The design of these alternatives is listed in Table 1.1 for the pink player.



Figure 1.1: Illustration of the level playing field network that is used in the gaming sessions.

Segment	Cost (€)	TTL (h/w)	Duration (weeks)	Delay (weeks)	Delay probability
B1-D					
LOW TTL	3,184,500	8,000	10	2	33 %
LOW COST	2,026,500	12,000	9	4	33 %
NO RISK	3,184,500	10,000	9	-	-
FAST	2,895,000	12,000	6	2	33 %
B11-A					
LOW TTL	5,778,000	1,760	9	2	33 %
LOW COST	3,676,500	2,640	8	4	33 %
NO RISK	5,778,300	2,200	8	-	-
FAST	5,253,000	2,640	6	2	33 %
B11-B					
LOW TTL	4,618,500	3,040	14	2	33 %
LOW COST	2,938,500	4,560	13	4	33 %
NO RISK	4,618,350	3,800	13	-	-
FAST	4,198,500	4,560	9	2	33 %
B11-C					
LOW TTL	1,848,000	1,120	6	1	33 %
LOW COST	1,176,000	1,680	5	2	33 %
NO RISK	1,848,000	1,400	5	-	-
FAST	1,680,000	1,680	4	1	33 %

Table 1.1: Maintenance portfolio of the pink player listing the available alternatives and their impact on the joint plan in terms of cost (euros), ttl (hours per week) and (potential) duration in weeks.

The alternatives listed in Table 1.1 are for the pink player but, due to the level playing field design, the values in this table apply also to the other players albeit for different road segments. Furthermore, the total cost and ttl of a method is presented to the player as an expected value estimate based upon the delay probability, the extension of duration and

regular cost. That is, the expected cost of an alternative is computed informally by the formula:

$$\mathbb{E}_{cost} = (1 - delay \ probability) \times cost + (delay \ probability) \times cost \times \frac{delay \ duration}{regular \ duration}$$
(1.1)

e.g. the LOW COST alternative for segment B1-D has an expected cost of $(1-0.33) \times 3$, 184, $500+0.33 \times 3$, 184, $500 \times \frac{10+2}{10} = 3$, 394, 677. For the ttl costs a similar estimate is applied, but ttl is also affected by the network due to the presence of the other players. This is described in the next paragraph. Note that the *actual* cost of a method follows from the execution of the game, when outcomes are realised at random for every method. In other words, either a task delays or does not due as a result of a stochastic process, and the cost to the player is either the listed cost or the cost plus delay time (e.g. $cost \times \frac{delay \ duration}{regular \ duration}$).

Network Model The traffic model underlying the network of the game is a factor-based model that represents the effect of maintenance on the road network throughput as sums of linear functions over averaged 'normal' traffic conditions. For every method m^r for road segment r and every other road segment $r' \neq r$ there exists a function of the form $f(m^r, r') \times \ell(r, t)$ that gives the increased traffic at road r due to the execution of m_x^r at time t concurrent with any maintenance on road r'. Notice that normally, in the absence of maintenance, the traffic time lost would have been $\ell(r, t)$. As only the increase in ttl with respect to the idle situation is interesting to measure, factors $f \in \mathbb{R}^+$ are used. Each player is charged an equal share of the total ttl increase caused by their joint plan, or:

$$\ell_i(\mathbf{y}, t) = \frac{\sum_{m^{r'} \neq m_i^r \in \mathbf{y}(t)} f(m_i^r, r') \times \ell(r, t)}{|\mathbf{y}(t)|}$$

In this formula, $\mathbf{y}(t)$ is shorthand notation for all methods at time t in joint plan \mathbf{y} and $m_i^r \in \mathbf{y}_i(t)$ the alternative chosen by player i for road segment r at time t. Note that $\mathbf{y}(t)$ contains at most one method of each player for every time t as they cannot perform two projects at once. Furthermore, the model is anonymous as the ttl costs are symmetric with respect to the players, i.e. $\ell_i(\mathbf{y}, t) = \ell_i(\mathbf{y}, t)$ for every $i, j \in \mathbf{N}$.

The idle traffic time lost values $\ell(r,t)$ are given in Table 1.2, where they are grouped in 4 week intervals. The ttl increase factors $f(m_x, r)$ are given in Table 1.3. Once more only the network matrix for the pink portfolio is shown in the latter table; the matrix for the other players is exactly the same but for the segment names.

						W	veek number	s					
Segments	1-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40	41-44	45-48	49-52
B1-A, B1-B, B1-C, B1-D, B1-E	9,640	11,148	14,649	15,134	15,134	8,886	15,080	8,348	8,132	15,565	14,326	19,173	18850
B2-A, B3-A, B4-A, B5-A, B6-A	1,687	1,951	2,564	2,648	2,648	1,555	2,639	1,461	1,423	2,724	2,507	3,355	3299
B2-B, B3-B, B4-B, B5-B, B6-B	16,630	19,231	25,270	26,106	26,106	15,329	26,013	14,400	14,029	26,849	24,713	33,074	32516
B11-A, B12-A, B13-A, B14-A, B15-A	1,938	2,241	2,945	3,042	3,042	1,786	3,031	1,678	1,635	3,129	2,880	3,854	3789
B11-B, B12-B, B13-B, B14-B, B15-B	3,516	4,066	5,343	5,519	5,519	3,241	5,500	3,045	2,966	5,677	5,225	6,993	6875
B11-C, B12-C, B13-C, B14-C, B15-C	1,938	2,241	2,945	3,042	3,042	1,786	3,031	1,678	1,635	3,129	2,880	3,854	3789
B21-A, B22-A, B23-A, B24-A, B25-A	658	761	999	1,032	1,032	606	1,029	569	555	1,062	977	1,308	1286
B21-B, B22-B, B23-B, B24-B, B25-B	658	761	999	1,032	1,032	606	1,029	569	555	1,062	977	1,308	1286
M1-A, M2-A, M3-A, M4-A, M5-A	4,243	4,906	6,447	6,660	6,660	3,911	6,637	3,674	3,579	6,850	6,305	8,438	8296

Table 1.2: TTL per week for each row segment, grouped per set of equivalent segments.

	B1-A	B1-B	B1-C	B1-D	B1-E	B2-A	B2-B	B3-A	B3-B	B4-A	B4-B	B5-A	B5-B	B6-A	B6-B
B1-D															
LOW TTL	.302	.302	.302	.603	-	.603	-	-	-	-	-	-	-	-	-
LOW COST	.452	.452	.452	.905	.905	.905	-	-	-	-	-	-	-	-	-
NO RISK	.377	.377	.377	.754	.377	.754	-	-	-	-	-	-	-	-	-
FAST	.452	.452	.452	.905	.905	.905	-	-	-	-	-	-	-	-	-
B11-A															
LOW TTL	-	-	-	-	-	-	.330	.660	-	.330	-	-	-	-	-
LOW COST	-	-	-	-	-	-	.495	.990	-	.495	-	-	-	-	-
NO RISK	-	-	-	-	-	-	.412	.825	-	.412	-	-	-	-	-
FASI	-	-	-	-	-	-	.495	.990	-	.495	-	-	-	-	-
B11-B	214	214	214					214		214		214			
LOW IIL	.514	.514	.314	-	-	-	-	.514	-	.514	-	.314	-	-	-
NO RISK	303	303	303	-	-	-	-	303	-	303	-	303	-	-	-
FAST	.471	.471	.471	-	_	_	_	.471	_	.471	_	.471	_	_	_
B11-C															
LOW TTL	-	-	-	-	-	-	-	-	-	210	210	420	-	-	-
LOW COST	-	-	-	-	-	-	-	-	-	.315	.315	.630	-	-	-
NO RISK	-	-	-	-	-	-	-	-	-	.262	.262	.525	-	-	-
FAST	-	-	-	-	-	-	-	-	-	.315	.315	.630	-	-	-
	B11-A	B11-B	B11-C	B12-A	B12-B	B12-C	B13-A	B13-B	B13-C	B14-A	B14-B	B14-C	B15-A	B15-B	B15-C
B1-D															
LOW TTL	-	-	-	-	-	-	-	-	-	-	-	.302	-	-	.302
LOW COST	-	-	-	-	-	-	-	-	-	-	-	.452	-	-	.452
NO RISK	-	-	-	-	-	-	-	-	-	-	-	.377	-	-	.377
FAST	-	-	-	-	-	-	-	-	-	-	-	.452	-	-	.452
B11-A															
LOW TTL	-	-	.660	.330	.660	.660	.330	.330	.330	-	-	-	-	-	.330
LOW COST	-	.990	.990	.495	.990	.990	.495	.495	.495	-	-	-	-	-	.495
NO RISK	-	.412	.825	.412	.825	.825	.412	.412	.412	-	-	-	-	-	.412
FASI	-	.990	.990	.495	.990	.990	.495	.495	.495	-	-	-	-	-	.495
BII-B		620		620	620	620	214	620	620	214	214	214			214
LOW IIL	_	.028	942	.028	.028	.028	.514	.028	.028	.514	.514	.514	_	-	.514
NO RISK	_	785	393	785	785	785	393	785	785	393	393	393	_	_	393
FAST	-	.942	.942	.942	.942	.942	.471	.942	.942	.471	.471	.471	-	-	.471
B11-C															
LOW TTL	-	.210	.420	-	.210	.210	-	.420	.420	.210	.210	.210	-	-	-
LOW COST	-	.315	.630	.630	.315	.315	-	.630	.630	.315	.315	.315	-	-	-
NO RISK	-	.262	.525	.262	.262	.262	-	.525	.525	.262	.262	.262	-	-	-
FAST	-	.315	.630	.630	.315	.315	-	.630	.630	.315	.315	.315	-	-	-
	DO1 :	Date	Dag :	Daar	Daa i	Daa F	DO1 /	DALE	D05 :	D05 F					N/7 ·
	В 21-А	B21-B	В 22-А	в22-В	В 2 3 -А	в23-В	В 24-А	в24-В	в25-А	в25-В	MI-A	M2-A	м3-А	м4-А	м5-А
B1-D												202		202	
LOW TTL	-	-	-	-	-	-	-	-	-	-	-	.302	-	.302	.603
LOW COST	-	-	-	-	-	-	-	-	-	-	-	.452	-	.452	.905
FAST	-	-	-	-	-	-	-	-	-	-	-	452	-	452	905
P11 A												.152		.152	.705
LOW TTI	330	330	-	-	-	-	-	-	-	-	330	330	330	-	-
LOW COST	.495	.495	_	-	-	_	_	_	-	_	.495	.495	.495	-	_
NO RISK	.412	.412	-	-	-	-	-	-	-	-	.412	.412	.412	-	-
FAST	.495	.495	-	-	-	-	-	-	-	-	.495	.495	.495	-	-
B11-B															
LOW TTL	.314	-	-	-	-	-	-	-	-	-	-	.314	.628	.314	-
LOW COST	.471	-	-	-	-	-	-	-	-	-	-	.471	.942	.471	-
NO RISK	.393	-	-	-	-	-	-	-	-	-	-	.393	.785	.393	-
FAST	.471	-	-	-	-	-	-	-	-	-	-	.471	.942	.471	-
B11-C															
LOW TTL	-	-	-	-	.210	.210	-	-	-	-	-	-	.210	.210	-
LOW COST	-	-	-	-	.315	.315	-	-	-	-	-	-	.315	.315	-
NU RISK	-	-	-	-	.262	.262	-	-	-	-	-	-	.262	.262	-
LUDI	-	-	-	-	.515	.515	-	-	-	-	-	-	.515	.515	-

Table 1.3: TTL factor matrix for every combination of method and road segment. Every cell contains the first 3 decimals of factor $f(m^r, r')$, i.e. $f(LOW COST^{BI-D}, BI-A) = 0.302$. A dash indicates a factor zero.

Gameplay The game is played in two phases: a planning phase and an execution phase. The planning phase is by far the most important phase. In this phase players develop and coordinate their maintenance plans, while receiving information about the plans of their competitors. The execution phase merely simulation the execution of the maintenance plans that have been developed as a result of the planning phase and is only meant to determine actual revenues for winner determination and "player excitement". The latter phase is explained later when discussing the winning criteria.



Figure 1.2: The user interface for the players: a Gantt chart that shows the current maintenance plans, a network that shows traffic interactions and insights into the impact of the current plan.

In the planning phase, each of the players are burdened with the task of developing a plan for the maintenance tasks in their assigned portfolio. On a Tablet PC that matches the colour of their player they are shown an interface similar to Figure 1.2 to plan their maintenance. For every project in their portfolio, a player has to decide how and when they will do the work by choosing one of the four methods described earlier and positioning it on the Gantt-like diagram in the top of the screen. The impact of their decisions in terms of cost and ttl is then computed and displayed in the bottom right table. Network relations are shown on the left to illustrate (possible) interactions with other player's tasks.

The planning process follows a round-based procedure. In each round, every player submits its maintenance plan for its own portfolio. When all plans have been submitted, the game will combine them all into a new *joint* maintenance plan and present this plan back to the players. Players then get the option to accept or reject this new plan. If all players accept, the planning phase is over and the execution phase will start. If at least one player declines, a new planning round starts in which now all players possess information about their competitors. All last submitted plans are preserved in the interface and shown to the players. As a consequence, players can now respond to the previously made decisions of other agents. Changes to the plan, however, are not shown real-time, hence players will have to request/await a new submission of all plans to know what changes the other players have made during the new round. Observe hence that the first round is always an individual planning round: in the first planning round no plans were previously submitted and hence no information about other players' decisions is available.

Winning the game The game can be won in two ways, mimicking to the misalignment between the contractor's individual goal (maximum profit) and the asset manager's global goal (maintenance with minimal traffic impact). In every session, the player that has the highest profit at the end of the game is declared the winner of that session and is rewarded a price. However the team, i.e. all players of a single session combined, that achieves the lowest expected ttl over all sessions is declared the network winner, and all members of this winning team are given a price. To incite a preference for the global goal and increase tension between both goals, the network price should be 'more valuable' to players than the profit price. In the gaming sessions of Scharpff et al. (2019), the profit price is a $\in 2.50$ scratch ticket whereas the 'bigger' team price is in the form of a $\in 10$ voucher for all network members. This will make it more interesting for players to pursue the global goal (also because of the competition against other teams) but still try to come out on top in a single gaming session, which is typically conflicting as the results of Chapter 3 show.

Winner determination is done in two ways. For a 'fair' comparison of all sessions, the ttl goal is measured as the expected hindrance of the final joint plan submitted by all players. In other words, this is established before going into the execution phase (but getting the lowest ttl still proved a difficult task). To determine the 'session winner', i.e. the

contractor with the highest profit, the execution phase is started. Essentially, the only purpose of the execution phase is to simulate the projects and in particular randomly realise task delays so that the 'actual' costs and ttl become known. Although an option exists that automates this process by randomly realising delays and presenting the results back to the players, a more fun method was used during the sessions to excite players and end the session on a happy note. During the sessions, the interface was used to progress in time one week at a time. If in that week a method starts that may possibly delay, the corresponding player was asked to throw a dice to determine the outcome of that task and that outcome was fed back into the game. Indeed, this resulted in some heated endings with players in a neck-to-neck race for the price.

Practical set-up The set-up consists of one PC/Laptop that hosts the game server and five client Tablet PCs that connect to the game server as players. The game itself is developed in Java and uses the Google Web Toolkit framework for the client/server architecture and the web-based interfaces of the game. Technically there are three: the player interface as described above, the game server interface to manage the game and its progress, and a "scoreboard" interface that shows the scores and ranking of the players. The source code and network model of the Maintenance Planning Game used in this article can be found at https://gitlab.com/jscharpff/maintenance-planning-game.



Figure 1.3: Four photos of the game in progress that show the setup and the interaction between players. In (a) the game is at an early stage and players are developing their individual plans on their Tablet PCs. In (b) and (c) the network planning is in full progress, where both pictures show that players in this session use a fully-coordinated decision making process to coordinate their dependencies (corresponding to the 'Very High' coordination level of Table 2.3). In particular, the whiteboard of (d) was used to regulate decision of all players. All participants in the photos agreed with the publication thereof in academic articles. The faces have been blurred to respect the privacy of the participants.

2 | Data Gathering Methodology

This chapter describes the data gathering methodology used to validate the hypotheses of Scharpff et al. (2019) in full detail. This section is separated into three parts corresponding to the different type of measurements obtained: the agent decision preference and rationality established a priori through the questionnaire, the qualitative performance data measured from the impact of decision made in-game and the quantitative session data observed over the course of the game. Note that this section only discusses the methodology itself; the measurements obtained from the initial gaming sessions can be found in Chapter 3

2.1 Agent decision preference and rationality

To establish the a priori decision-rationality of participants a questionnaire is used. This questionnaire poses 7 increasingly more complex decision-making scenarios from the maintenance planning domain, asking participants to rank alternatives according to their preference. Whereas the first question is relatively easy and has a 'correct' answer, i.e. the alternatives can be clearly ordered according to their ttl impact, the subsequent questions become increasingly more complex. This is due to the introduction of new factors into the decision making process such as profits, delays and the presence of other service providers. Furthermore, the alternatives mostly depends on personal preference, that is, the decision rationality of the participants. The questionnaire is included below:

Dynamic Network Planning Questionnaire

Name: Date: Occupation and position

Question 1

You are a service provider responsible for the maintenance of a road segment in a regional network. To this end, you have studied the impact on traffic of four possible alternatives. This results in the following congestion figures, expressed in hours of traffic time lost (TTL), caused by each alternative.

	Alternative A	Alternative B	Alternative C	Alternative D
TTL	352.000	578.000	440.000	370.000

 a) Can you specify the order in which you would choose from the various alternatives? Please rank them from 1 (best) to 4 (worst).

Answer:	Rank:
Alternative A	
Alternative B	
Alternative C	
Alternative D	

b) Please motivate your ranking.

Question 2

In addition you perform cost computation, resulting in the following figures:

	Alternative A	Alternative B	Alternative C	Alternative D
TTL	352.000	578.000	440.000	370.000
Profit	€ 1.450.000	€ 2.108.000	€ 1.500.000	€ 1.739.000

a) Can you specify the order in which you would choose from the various alternatives? Please rank them from 1 (best) to 4 (worst).

Answer:	Rank:
Alternative A	
Alternative B	
Alternative C	
Alternative D	

b) Please motivate your ranking.

Question 3

The road authority decides to implement a traffic penalty payment that charges the service provider 1 euro for each hour of TTL. After some recalculation you find out that this has the following impact on your project:

	Alternative A	Alternative B	Alternative C	Alternative D
TTL	352.000	578.000	440.000	370.000
Profit	€ 1.098.000	€ 1.529.000	€ 1.060.000	€ 1.369.000

a) Can you specify the order in which you would choose from the various alternatives? Please rank them from 1 (best) to 4 (worst).

Answer:	Rank:
Alternative A	
Alternative B	
Alternative C	
Alternative D	

b) Please motivate your ranking

Question 4

You are aware of the possibility that your project execution might be delayed and you are wondering how much that will affect the figures from before. Therefore you decide to also consider this delay in your computations:

Situation	Risk of delay		Alt. A	Alt. B	Alt. C	Alt. D
Project	67%	TTL	352.000	578.000	440.000	370.000
planned	0776	Profit	€ 1.098.000	€ 1.529.000	€ 1.060.000	€ 1.369.000
Project is	220/	TTL	443.000	885.000	440.000	503.000
delayed	3370	Profit	€ 1.006.000	€ 1.223.000	€ 1.060.000	€ 1.236.000

 a) Can you specify the order in which you would choose from the various alternatives? Please rank them from 1 (best) to 4 (worst).

Answer:	Rank:
Alternative A	
Alternative B	
Alternative C	
Alternative D	

b) Please motivate your ranking.

Question 5

You have chosen four potential periods in which you can perform your project. Using quarterly figures, you determine the following prospects regarding four possible maintenance periods:

Situation	Risk of delay		Period 1	Period 2	Period 3	Period 4
Project	67%	TTL	370.000	416.000	333.000	615.000
planned	0778	Profit	€ 1.369.000	€ 1.323.000	€ 1.406.000	€ 1.124.000
Project is	220/	TTL	503.000	571.000	493.000	809.000
delayed	33%	Profit	€ 1.236.000	€ 1.168.000	€ 1.246.000	€ 930.000

In addition, you also possess information regarding the TTL figures of the previous year.



a) Can you specify the order of periods in which you prefer to perform the maintenance? Please rank them from 1 (best) to 4 (worst).

Answer:	Rank:	
Period 1		
Period 2		
Period 3		
Period 4		

b) Please motivate your ranking.

Question 6

Other service providers are also working in this region and they, in combination with your project, cause additional traffic hindrance:

Situation	Risk of delay		Period 1	Period 2	Period 3	Period 4
Project	67%	TTL	370.000	416.000	333.000	615.000
planned	0776	Profit	€ 1.369.000	€ 1.323.000	€ 1.406.000	€ 1.124.000
Project is delayed	220/	TTL	503.000	571.000	493.000	809.000
	3376	Profit	€ 1.236.000	€ 1.168.000	€ 1.246.000	€ 930.000

Situation	Risk of delay		Period 1	Period 2	Period 3	Period 4
Project		TTL Ind.	370.000	416.000	333.000	615.000
as	67%	TTL Net.	990.000	2.033.000	3.966.000	1.302.000
planned		Profit	€ 1.171.000	€ 916.000	€ 613.000	€ 863.000
Project		TTL Ind.	414.000	471.000	406.000	667.000
is	33%	TTL Net.	2.030.000	2.662.000	6.545.000	1.436.000
delayed		Profit	€ 919.000	€ 736.000	€ 24.000	€ 785.000

In this table, the individual TTL denotes the TTL caused solely by your project, ignoring others. The network TTL captures the 'combined effect' of multiple service providers working concurrently in the same region. Next to this table, you are also given a plot of the TTL distribution over time.



a) Can you specify the order in which you would choose from the various periods? Please rank them from 1 (best) to 4 (worst).

Answer:	Rank:
Period 1	
Period 2	
Period 3	
Period 4	

b) Please motivate your ranking.

Question 7

You have chosen the third period and you wish to reduce the incurred traffic time losses. Through communication with the other contractors, you have been able to create the following joint schedule:



 a) If you were given the opportunity to change plans made by others, what project(s) would you modify? Can you rank the projects based on which one you would modify first (1) to last (4)?

Rank:

b) Please motivate your ranking.

Thank you very much for completing this questionnaire!

To measure the decision preference and rationality, the submitted responses are evaluated against pre-determined rankings of alternatives per question and objective. In other words, for every question n and objective m there is a ranking of objectives O_n^m that lists the alternatives in their order from best to worst. For example, the profit ordering of question 2 is the ranking $O_2^p = (4, 1, 3, 2)$ as alternative B yields the most profit and A the least. For the ttl, on the other hand, the ranking is given by $O_2^t = (1, 4, 3, 2)$ as the lowest hindrance is caused by alternative A. Note that here numerical indexes are used instead of the alphabetical index in the questionnaire, this is more convenient when computing scores. For each objective the ranking is determined according to the following rules:

- The profit ranking O^p is given by the expected profit of an alternative, ordered from highest to lowest. When the probability of delay is zero, the profit is simply the profit as listed (questions 1 to 4). In the case of potential delay, the expected profit is computed as $(1 p) \times P_{planned} + p \times P_{delayed}$ in which p is the probability of delay (0 or 0.33) and $P_{planned}$ and $P_{delayed}$ the listed profit when respectively the maintenance is performed according to plan or a delay is encountered.
- The ttl ranking O^t is determined by the expected ttl, ordered from lowest (best) to highest (worst). Similar to profit, the ttl score is also computed by the expected ttl in the presence of delay. Moreover, in the presence of other service providers an additional ttl component 'Network' is factored into the computation, i.e. $(1 p) \times (T_{ind,planned} + T_{net,planned}) + p \times (T_{ind,delayed} + T_{net,delayed})$ such that $T_{ind,x}$ and $T_{net,x}$ express the listed individual and network ttl for the planned and delayed scenarios. Note that it is assumed that work by other contractors does not delay (or always does) to keep the influence of the network on ttl simple.
- The risk(-aversion) ranking O^r is ordered on the expected loss of revenue due to delay from lowest to highest potential loss. In other words, the risk aversion score is the highest when the effect of delay is the least and lowest when a delay causes high revenue decreases. The formula to compute this loss is $(P_{planned} T_{planned}) (P_{delayed} T_{delayed})$ due to the design of payments such that every hour of ttl incurs a cost of 1 euro (with $T_x = T_{ind,x} + T_{net,x})$.

		Pr	ofit			TTL				Risk-aversion			
Question #	Α	В	С	D	Α	В	С	D	Α	В	С	D	
1	-	-	-	-	1	4	3	2	-	-	-	-	
2	4	1	3	2	1	4	3	2	-	-	-	-	
3	3	1	4	2	1	4	3	2	-	-	-	-	
4	2	4	3	1	1	4	3	2	2	4	1	3	
5	2	3	1	4	2	3	1	4	1	2	3	4	
6	1	2	4	3	1	3	4	2	3	2	4	1	
7	-	-	-	-	3	4	2	1	-	-	-	-	

Table 2.1: Rank of alternatives per question and objective from best (1) to worst (4). The entries marked as '-' indicate a no-score in that objective, due to absence of the objective.

Using these predefined rankings per objective, Table 2.1 is obtained that contains the rankings for every alternative per question and objective. Now, given a complete questionnaire response that is composed of rankings $\mathbf{x} = (x_1, x_2, \dots, x_7)$, such that x_i ranks the alternatives for question *i* from best to worst, the rankings per objective can be used to compute a relative score that expresses how the participant performs in each of the objectives. This relative score is termed the *player profile score* and is an indication for the decision-making preference of the participants. To compute the profile scores, first the objective rankings of Table 2.1 are converted into weights for each alternative. Then, the submitted ranking of alternatives for each question is aggregated into a single score using the multi-criteria decision-making scoring of (Roszkowska 2013, Triantaphyllou 2013).

The weighting of alternatives is performed according to the rank-order centroid (ROC) formula proposed initially by Barron and Barrett (1996). ROC is often used in decision making theory when the relative rank ordering is known but no meaningful quantitative information is available about the alternatives. It has the property of minimising the maximum error of each weight and typically generates weight vectors that are comparable to those produced by panels of subject matter experts. Assuming that the four weights are uniformly distributed, the weight for each alternative is computed as its expected value by $\mathbb{E}(w_j) = 1/n \sum_{k=j}^{n} 1/k$, where w_j is the weight for the alternative at rank position j. In the case of four alternatives this yields the weight vector (.521, .271, .146, .063), ordered from best to worst alternative. By combining the relative rank ordering with the rank weights, the weighted rank score S_i^m per attribute m is determined for every problem i of the questionnaire by simply replacing the ranks $j \in [1, 4]$ of ordering O_i^m by their respective rank weights w_j . Thus, the ordering $O_5^p = (2, 3, 1, 4)$ of alternatives of question 5 with respect to expected profits becomes the score vector $S_5^p = (.271, .146, .521, .063)$. Similar substitutions can be performed to generate all alternative weights.

The weighted rank scores enable to measuring and comparing questionnaire responses on a quantified scale. Again a single, complete questionnaire response is denoted by $\mathbf{x} = (x_1, x_2, \dots, x_7)$, with x_i being the ranking of alternatives for question *i* as submitted by the participant. As before, a ranking is a vector that for every alternative specifies the preferred order from best (1) to worst (4). Given a ranking x_i for question *i*, the (unscaled) profile score for objective *m* is then computed by $q_m(x_i) = \sum_{k=1}^{4} (5 - x_{i,k}) \times S_{i,k}^m$, such that $5 - x_{i,k}$ ensures that the first ranked alternative has a weight of

4 and the least preferred option gets a weight of 1. Given a questionnaire response \mathbf{x} , the preference score of a participant for objective m is the normalised sum of scores over all questions:

$$\hat{Q}_m(\mathbf{x}) = \frac{\sum_{i=1}^{|\mathbf{x}|} q_m(x_i) - Q_m^{min}}{Q_m^{max} - Q_m^{min}}$$
(2.1)

where Q_m^{min} and Q_m^{max} are respectively the minimum and maximum attainable scores for objective *m* computed over all possible rankings of alternatives. Then from the preference scores over all objectives, the actual profile score can be computed as its relative importance using the formula:

$$Q_m(\mathbf{x}) = \frac{\hat{Q}_m(\mathbf{x})}{\sum_{k \in \{p,t,r\}} \hat{Q}_k(\mathbf{x})}$$
(2.2)

Finally, the *rationality* of the questionnaire responses is measured in terms of their distances to the closest Paretooptimal score and closest minimum score, also known as the normalised Pareto distance (Rousis 2011). Given a complete questionnaire score $\mathbf{q} = (Q_p(\mathbf{x}), Q_t(\mathbf{x}), Q_r(\mathbf{x}))$ with the symbols p for profit, t for ttl and r for risk-aversion, decision rationality is then expressed as the Euclidean distance of \mathbf{q} to the closest Pareto-optimal score b inversely related to the sum of Euclidean distances to score b and closest lowest score w:

$$\theta(\mathbf{q}) = 1 - \frac{||\mathbf{b} - \mathbf{q}||}{||\mathbf{b} - \mathbf{q}|| + ||\mathbf{w} - \mathbf{q}||}$$
(2.3)

Here, the closest Pareto scores **b** and **w** are determined by checking the distance from **q** to all other scores. The sets of the worst and best Pareto scores for the questionnaire responses are computed using a simple Java program that can be found in the code base on GitLab at https://gitlab.com/jscharpff/maintenance-planning-game.

2.2 Player/team Strategy

The in-game actions are scored based on their impact on each of the objectives as discussed in Chapter 1. Each maintenance alternative available to the players in the game is attributed scores for profit, ttl and risk-aversion, and they are ranked from best to worst, similar to the ranking of the previous section. These rankings are shown in Table 2.2.

Method	G_p	G_t	G_r
LOW TTL	4	1	2
LOW COST	1	4	4
NO RISK	3	3	1
FAST	2	2	3

Table 2.2: Rank of each maintenance method per objective from best (1) to worst (2).

From these rankings the *strategy score* for a player is computed from his/her submitted maintenance plan as follows. For a single player $i \in \mathbb{N}$, a maintenance plan is given by

$$\mathbf{y}_k = (\langle m_1^i, t_1^i \rangle, \langle m_2^i, t_2^i \rangle, \langle m_3^i, t_3^i \rangle, \langle m_4^i, t_4^i \rangle)$$

such that each $\langle m_k^i, t_k^i \rangle$ represents the chosen alternative m_k^i and start time t_k^i of maintenance task k. The played preference score G_p of player i is then

$$\hat{G}_{p}(\mathbf{y}_{i}) = \frac{\sum_{m_{k}^{i} \in \mathbf{y}_{i}} g_{p}(m_{k}^{i}) - G_{p}^{min}}{G_{p}^{max} - G_{p}^{min}}$$
(2.4)

in which $g_p(m_k^i)$ is the (non-normalised) profit score for method m_k^i of task k and G_{min}^p and G_{max}^p denote respectively the minimum and maximum profit scores attainable in game. As with the profile scores of Section 2.1, the profit strategy score G_p , the strategy score G_t and risk-aversion strategy score G_r are computed relative to the other preferences, thus:

$$G_m(\mathbf{y}_i) = \frac{G_m(\mathbf{y}_i)}{\sum_{k \in \{p,r,t\}} \hat{G}_k(\mathbf{y}_i)}$$
(2.5)

and strategy scores of a session are aggregated using the average strategy score over all teams.

The performance of players with respect to game outcomes is also scored. To this end, the expected profit, traffic time lost and performance are measured as a function of the former two, similar to the model of Scharpff et al. (2013). The

expected profit of a player *i* given its plan y_i , denoted by $P_i(y_i)$, is defined as the expected reward of completing work minus the expected costs thereof, or

$$P_{i}(\mathbf{y}_{i}) = \sum_{m_{k}^{i} \in \mathbf{y}_{i}} \left(W(m_{k}^{i}) - \sum_{t=t_{k}^{i}}^{t_{k}^{i}+d(m_{k}^{i})} C(m_{k}^{i},t) - p(m_{k}^{i}) \sum_{t=t_{k}^{i}}^{t_{k}^{i}+d(m_{k}^{i})} C(m_{k}^{i},t) \right)$$
(2.6)

such that $d(m_k^i)$ and $\hat{d}(m_k^i)$ denote respectively the regular and extended maintenance period, the latter only applies when the task is delayed with probability $p(m_k^i)$. Furthermore, $W(m_k^i)$ is the fixed, contracted reward received upon completion of the task associated with m_k^i (thus independent from the chosen method) and $C(m_k^i, t)$ the maintenance cost of performing method m_k^i at time t.¹

For the traffic time lost $T_i(\mathbf{y})$ caused by player *i*, given *joint* plan $\mathbf{y} = \bigcup_{i \in \mathbb{N}} \mathbf{y}_i$ with the set of players $\mathbb{N} = \{1, 2, \dots, 5\}$, a similar expected value computation is made. Notice that for the computation of ttl a joint plan is required as concurrent maintenance can have super-linear impact on traffic. The ttl model of the game is defined through a function $\ell_i(\mathbf{y}, t)$ (Chapter 1) that returns the ttl caused by player $i \subseteq \mathbb{N}$ at time t when joint plan y is executed. Therefore, the total ttl caused by an individual player i is given by²

$$T_{i}(\mathbf{y}) = \sum_{m_{k}^{i} \in \mathbf{y}_{i}} \left(\sum_{t=t_{k}^{i}}^{t_{k}^{i}+d(m_{k}^{i})} \ell_{i}(\mathbf{y},t) + p(m_{k}^{i}) \sum_{t=t_{k}^{i}}^{t_{k}^{i}+d(m_{k}^{i})} \ell_{i}(\mathbf{y},t) \right)$$
(2.7)

With the aforementioned formulas the expected utility of a player *i* is expressed as the sum of its expected revenue minus the monetary value of the expected ttl. Consequentially, expected profit for a player *i* given a joint plan y, such that $y_i \in y$ is the plan of player *i*, is given by $u_i(y) = P_i(y_i) - T_i(y)$. Finally, similar to the decision rationality of profile scores, an indication of the quality of the in-game decisions can be defined over the strategy scores. The *performance ratio* $\phi(y)$ for a given joint plan y expresses the ratio between profit and ttl:

$$\phi(\mathbf{y}) = \frac{P(\mathbf{y})}{T(\mathbf{y})} \tag{2.8}$$

and observe that this value increases either when the joint profit increases, the joint ttl decreases or both. Hence a higher performance ratio indicates a better overall outcome.

2.3 Session metadata

In addition to the qualitative measurements, two of quantitative measurements is also defined that characterise the sessions in terms of coordination and familiarity between players in a single session. These characteristics have not been measured in terms of some absolute figure; in stead they are determined based on observations made prior to and during the gaming sessions. The coordination level is determined during the session itself and is set to the highest degree of collaboration observed. For instance, in a session where players use plenary sessions to coordinate decision but do not apply governed decision making, the coordination level is set to 'Medium'. Finally, the cohesion level is determined mostly a priori and confirmed with the group at the start of the session. All the qualitative measurements are defined in Table 2.3.

	Description
Coordination level	
Low	Conflict-driven coordination of interactions via bilateral or trilateral negotiations
Medium	Coordination of network via democratic, plenary negotiations
High	Centralised planning that governs network decisions
Cohesion level	
Unfamiliar	Players have (had) limited to no interaction previously
Familiar	Players see and/or work with each other on a regular basis

Table 2.3: Definition of the qualitative categories for each of the data points obtained through observation with their abbreviations and a short description.

¹The reward and cost functions have no player index as the underlying model is the same.

²No time step t is counted more than once due to the one-task-at-a-time restriction.

3 | Results from the sessions

This chapter summarises the results of all measurements taken from this session, both a priori as well as during the session. In total, 7 gaming sessions have been performed with 95 players from various ages, institutions and backgrounds. Each of the sessions is given a letter for identification purpose and the characteristics of these sessions are listed in Table 3.1.

	Company/institute Profile	#P	#Q	Category	Coordination	Cohesion
А	University, Computer Science	9	9	Students	Low	Unfamiliar
В	ICT-focused R&D Company	10	9	Engineers	Low	Familiar
С	Utility provider, mainly power	15	3	Professionals	Low	Unfamiliar
D	Dutch national road authority	17	16	Trainees / Interns	High	Familiar
Е	Dutch national road authority	8	5	Trainees / Interns	Medium	Familiar
F	AM Professionals Course	20	9	Professionals	Medium	Unfamiliar
G	AM and Health-care Consultants	16	9	Professionals	High	Familiar

Table 3.1: Outline of game session characteristics, from left to right the columns are: session identifier, company/institute, number of participants, number of questionnaires reviewed, participants skill category, and the observed coordination and social cohesion of participants.

3.1 Questionnaire Responses

From the 95 participants, 59 valid questionnaires were collected. All of these responses have been scored according to Equation 2.2 and are listed in Table 3.2 on the next page. The columns capture respectively the session name, the computed profit, ttl and risk-aversion profile scores $(Q_p, Q_t \text{ and } Q_r)$, and the decision rationality θ . The average profile score of the session is included in the bottom row, included only for reference and is not used. The rationality scores are found using Equation 2.2 of the appendix, where the optimal Pareto trade-offs have been computed using a Java program that can be found in the GitLab repository.

	Q_p	Q_t	Q_r	θ			Q_p	Q_t	Q_r	θ
Session A					Se	ssion E				
	0.455	0.336	0.209	0.795			0.386	0.341	0.273	0.948
	0.436	0.352	0.212	0.802			0.379	0.367	0.254	0.913
	0.481	0.274	0.244	0.855			0.420	0.313	0.267	0.815
	0.440	0.338	0.221	0.815			0.473	0.315	0.212	0.845
	0.322	0.373	0.305	0.932			0.463	0.314	0.223	0.891
	0.475	0.350	0.175	0.730		avg	0.424	0.330	0.246	0.882
	0.465	0.321	0.213	0.773		_				
	0.385	0.384	0.231	0.845	Se	ssion F				
	0.253	0.464	0.284	0.385			0.307	0.457	0.236	0.713
avg	0.412	0.355	0.233	0.770			0.432	0.260	0.308	0.862
							0.483	0.338	0.178	0.715
Session B							0.459	0.343	0.198	0.789
	0.244	0.375	0.382	0.955			0.190	0.413	0.397	0.802
	0.459	0.343	0.198	0.789			0.325	0.431	0.243	0.887
	0.230	0.401	0.369	0.883			0.383	0.336	0.281	0.987
	0.244	0.460	0.296	0.691			0.337	0.425	0.237	0.731
	0.277	0.449	0.274	0.878			0.433	0.316	0.251	0.827
	0.375	0.375	0.250	0.897		avg	0.372	0.369	0.259	0.813
	0.369	0.395	0.236	0.870		0				
	0.360	0.380	0.259	0.904	Se	ssion G				
	0.459	0.343	0.198	0.789			0.380	0.355	0.266	0.933
avg	0.335	0.391	0.274	0.851			0.340	0.393	0.266	0.933
							0.467	0.336	0.197	0.790
Session C							0.353	0.377	0.270	0.932
	0.379	0.367	0.254	0.913			0.311	0.438	0.252	0.879
	0.428	0.321	0.251	0.849			0.350	0.340	0.310	0.961
	0.329	0.358	0.314	0.962			0.254	0.378	0.368	0.963
avg	0.379	0.348	0.273	0.908			0.278	0.446	0.276	0.886
-							0.394	0.347	0.260	0.922
Session D						avg	0.347	0.379	0.274	0.911
	0.272	0.358	0.370	0.958						
	0.401	0.345	0.254	0.255						
	0.455	0.336	0.209	0.795						
	0.459	0.343	0.198	0.789						
	0.426	0.355	0.219	0.884						
	0.398	0.375	0.227	0.855						
	0.350	0.417	0.233	0.877						
	0.326	0.378	0.297	0.916						
	0.327	0.377	0.296	0.982						
	0.381	0.384	0.235	0.853						
	0.431	0.342	0.227	0.880						
	0.335	0.447	0.218	0.710						
	0.266	0.319	0.415	0.838						
	0.347	0.400	0.253	0.907						
	0.336	0.404	0.260	0.938						
	0.349	0.264	0.387	0.974						
avg	0.366	0.365	0.269	0.838						

Table 3.2: Complete overview of questionnaire profile scores, grouped per session. For each response the profit, ttl and risk-aversion profile scores are computed (resp. Q_p , Q_t and Q_r) and the decision rationality θ according to Equation 2.3.

3.2 Session Outcomes

The in-game results are listed as a single table per game session. Each table contains multiple sub-tables, one for every round played in the game, and the listed figures are the values measured exactly when all players submitted their plan. Per round, the tables list for both the profit and ttl objectives the maximum value that can be obtained, the maximum impact of delay on that value and the expected value. For example, at the end of round 1 of session A, the Red player can potentially achieve a maximum profit of $\in 5, 425$. If the player is really unlucky and all of its activities are delayed, its profit decreases by $\in 6, 464$, resulting in a total loss of $\in 1, 039$. In expectation, however, its profit is $\in 3, 270$ which is of course much better than the worst-case scenario. The ttl columns are similar but for the fact that the figure in the delay column is *added* to the ttl figure in the case of delay. Note that the score listed in the last round is the score before the execution starts.

Session A	Profit	Delay	E[P]	TTL	Delay	E[T]	Session	B Profit	Delay	E[P]	TTL	Delay	E[T]
Round 1							Round	1					
Black	4.878	-6.748	2.629	6.179	2.721	7.086	Black	3.918	-5.986	1.923	5.766	1.946	6.415
Blue	3.273	-3.446	2.124	6.390	1.107	6.759	Blue	3.696	-5.289	1.933	7.257	2.079	7.950
Pink	2.907	-4.028	1.564	6.216	893	6.514	Pink	4.269	-6.521	2.095	6.824	2.506	7.659
Red	5.425	-6.464	3.270	5.632	2.438	6.445	Red	5.842	-7.297	3.410	6.287	3.234	7.365
White	5.347	-5.647	3.465	5.158	1.441	5.638	White	e 88	-3.873	-1.203	6.934	984	7.262
Total	21.830	-26.333	13.052	29.575	8.600	32.442	Total	17.813	-28.966	8.158	33.068	10.749	36.651
Round 2							Round	2					
Black	4.878	-6.748	2.629	5.512	2.735	6.424	Black	4.688	-5.636	2.809	3.240	1.158	3.626
Blue	5.646	-6.094	3.615	5.095	2.578	5.954	Blue	4.089	-4.935	2.444	4.639	1.726	5.214
Pink	5.745	-5.796	3.813	5.799	2.139	6.512	Pink	4.269	-6.521	2.095	3.753	2.389	4.549
Red	5.456	-6.279	3.363	550	2.177	1.276	Red	6.971	-6.352	4.854	4.968	2.832	5.912
White	6.183	-6.208	4.114	4.322	2.001	4.989	White	e 1.519	-3.771	262	4.450	841	4.730
Total	27.908	-31.125	17.533	21.278	11.630	25.155	Total	21.536	-27.215	12.464	21.050	8.946	24.032
Round 3							Round	3					
Black	4.989	-6.226	2.914	5.912	2.387	6.708	Black	5.095	-5.472	3.271	3.144	803	3.412
Blue	5.646	-6.094	3.615	6.264	1.711	6.834	Blue	6.693	-6.808	4.424	5.673	2.148	6.389
Pink	6.449	-6.019	4.443	5.029	2.955	6.014	Pink	6.491	-6.176	4.432	4.569	1.975	5.227
Red	7.242	-7.292	4.811	5.590	3.246	6.672	Red	7.762	-6.724	5.521	4.166	2.588	5.029
White	5.927	-5.010	4.257	4.816	1.854	5.434	White	e 1.899	-4.043	551	5.123	1.144	5.504
Total	30.253	-30.641	20.039	27.611	12.153	31.662	Total	27.940	-29.223	18.199	22.675	8.658	25.561
							Round	4					
							Black	5,095	-5.472	3.271	3,086	1.009	3.422
							Blue	7.565	-6.492	5.401	4.825	2.379	5.618
							Pink	6.927	-5.927	4.951	4.591	1.820	5,198

Red

White

Total

8.005

1.960

29.552

-6.469

-3.943

-28.303 20.118

5.849

646

4.465

5.045

22.012

2.277

998

8.483 24.840

5.224

5.378

Session C	Profit	Delay	E[P]	TTL	Delay	E[T]
Round 1						
Black	6.797	-6.692	4.566	5.837	2.579	6.697
Blue	5.602	-6.532	3.425	5.659	2.404	6.460
Pink	5.040	-6.427	2.898	4.793	2.382	5.587
Red	3.377	-4.433	1.899	5.747	1.650	6.297
White	6.204	-6.810	3.934	6.429	2.697	7.328
Total	27.020	-30.894	16.722	28.465	11.712	32.369
Round 2						
Black	6.797	-6.692	4.566	5.744	2.271	6.501
Blue	5.859	-6.329	3.749	5.402	2.277	6.161
Pink	5.741	-6.449	3.591	4.058	2.000	4.725
Red	3.377	-4.433	1.899	5.271	1.650	5.821
White	6.978	-6.742	4.731	5.660	2.207	6.396
Total	28.752	-30.645	18.537	26.135	10.405	29.603
Round 3						
Black	5.479	-4.901	3.845	5.097	1.482	5.591
Blue	7.163	-6.599	4.963	5.212	2.086	5.907
Pink	6.524	-6.636	4.312	3.791	1.858	4.410
Red	3.566	-3.292	2.469	4.565	1.092	4.929
White	6.978	-6.742	4.731	4.882	2.245	5.630
Total	29.710	-28.170	20.320	23.547	8.763	26.468
Round 4						
Black	5.662	-5.224	3.921	4.711	1.820	5.318
Blue	6.855	-4.857	5.236	4.579	1.369	5.035
Pink	7.691	-6.654	5.473	4.055	2.084	4.750
Red	3.566	-3.292	2.469	4.697	1.044	5.045
White	8.100	-6.179	6.040	4.951	2.195	5.683
Total	31.874	-26.206	23.139	22.993	8.512	25.830

Session D	Profit	Delay	E[P]	TTL	Delay	E[T
Round 1						
Black	2.582	-1.326	2.140	4.729	361	4.84
Blue	6.044	-5.722	4.137	4.461	1.515	4.96
Pink	3.825	-2.941	2.845	4.158	846	4.44
Red	7.898	-6.326	5.789	4.735	2.212	5.47
White	5.986	-4.675	4.428	5.489	1.462	5.97
Total	26.335	-20.990	19.338	23.572	6.396	25.70
Round 2						
Black	3.583	-1.326	3.141	2.657	204	2.72
Blue	6.241	-5.853	4.290	2.972	920	3.27
Pink	3.249	-2.248	2.500	3.078	486	3.24
Red	5.884	-5.033	4.206	2.541	964	2.86
White	4.010	-3.498	2.844	3.012	609	3.21
Total	22.967	-17.958	16.981	14.260	3.183	15.32
Round 3						
Black	3.702	-1.326	3.260	3.171	204	3.23
Blue	6.241	-5.853	4.290	2.774	1.110	3.14
Pink	3.011	-2.248	2.262	3.312	446	3.46
Red	6.152	-5.329	4.376	3.141	1.324	3.58
White	4.418	-3.760	3.165	3.193	678	3.41
Total	23.524	-18.516	17.352	15.591	3.762	16.84

Session E	Profit	Delay	E[P]	TTL	Delay	E[T]
Round 1						
Black	5 993	-4 215	4 588	4 223	973	4 547
Blue	3 678	-1.835	3.066	3 932	482	4 093
Pink	5 712	-4 779	4 1 1 9	4 084	1 173	4 475
Red	5 001	-3 865	3 713	4 291	970	4 614
White	4 512	-5 109	2,809	3 996	1 263	4 4 17
Total	24 896	-19 803	18 295	20 526	4 861	22.146
Total	21.070	19.005	10.275	20.020	1.001	22.110
Round 2						
Black	5.993	-4.215	4.588	3.751	923	4.059
Blue	4.417	-1.726	3.842	3.218	403	3.352
Pink	5.568	-4.493	4.070	3.925	850	4.208
Red	5.802	-5.005	4.134	3.727	1.205	4.129
White	5.006	-5.026	3.331	3.378	892	3.675
Total	26.786	-20.465	19.964	17.999	4.273	19.423
Round 3						
Black	5.924	-4.187	4.528	3.420	1.025	3.762
Blue	4.561	-1.700	3.994	3.267	347	3.383
Pink	6.377	-4.678	4.818	3.307	1.054	3.658
Red	6.032	-5.034	4.354	3.722	983	4.050
White	5.006	-5.023	3.332	3.580	720	3.820
Total	27.900	-20.622	21.026	17.296	4.129	18.672
Round 4						
Plack	5 700	1 242	1 276	2 560	1.015	2 007
Blue	6 688	-3.910	5 385	3 355	698	3 588
Diuc	6 377	4 678	1 818	3 170	1 1 1 4	3 550
Red	6.413	-5 156	4.616	3 660	1.114	4 045
White	5.006	-5.026	3.331	3.675	826	3.950
Total	30.274	-23.013	22.603	17.438	4.809	19.041
D 15						
Round 5						
Black	5.790	-4.243	4.376	3.651	1.015	3.989
Blue	6.655	-4.065	5.300	3.501	853	3.785
Pink	6.377	-4.678	4.818	3.230	1.176	3.622
Red White	6.413 5.006	-5.150	4.694	3.122	1.150	4.107
white	3.000	-5.020	5.551	5.045	5 025	5.916
Iotal	30.241	-23.168	22.518	17.747	5.025	19.422
Round 6						
Black	5.790	-4.243	4.376	3.805	1.180	4.198
Blue	6.547	-3.955	5.229	3.706	764	3.965
Pink	7.406	-5.464	5.585	3.521	1.585	4.049
Red	6.413	-5.156	4.694	3.794	1.171	4.184
White	4.899	-5.077	3.207	3.681	851	3.965
Total	31.055	-23.895	23.090	18.507	5.551	20.357
Round 7						
Black	5.779	-4.348	4.330	4,715	1.297	5.147
Blue	6,796	-4,164	5,408	4.686	1.189	5.082
Pink	7.406	-5.464	5.585	4.143	1.849	4.759
Red	7.893	-5.949	5.910	5.261	1.859	5.881
White	4.899	-5.077	3.207	4.296	1.188	4.692
Total	32.773	-25.002	24.439	23.101	7.382	25.562

Session F	Profit	Delay	E[P]	TTL	Delay	E[T]	Session G	Profit	Delay	E[P]	TTL	Delay	E[T]
Round 1							Round 1						
Black	4.008	-4.699	2.442	6.208	1.457	6.694	Black	4.415	-6.525	2.240	8.219	2.412	9.023
Blue	5.119	-6.227	3.043	5.386	2.020	6.059	Blue	3.683	-6.793	1.419	6.822	2.586	7.684
Pink	4.752	-4.061	3.398	5.044	1.115	5.416	Pink	4.716	-6.798	2.450	7.917	2.684	8.812
Red	5.480	-6.861	3.193	6.481	2.910	7.451	Red	3.972	-5.413	2.168	7.504	2.200	8.237
White	5.242	-5.183	3.514	5.712	1.974	6.370	White	1.851	-5.718	-55	6.405	2.069	7.095
Total	24.601	-27.031	15.591	28.831	9.476	31.990	Total	18.637	-31.247	8.221	36.867	11.951	40.851
Round 2							Round 2						
Black	5.625	-4.619	4.085	3.323	1.378	3.782	Black	6.342	-5.908	4.373	4.414	1.413	4.885
Blue	5.420	-6.081	3.393	4.317	1.492	4.814	Blue	4.323	-3.642	3.109	3.870	851	4.154
Pink	6.556	-4.204	5.155	3.766	963	4.087	Pink	5.947	-3.488	4.784	3.716	1.149	4.099
Red	7.267	-6.324	5.159	4.912	1.488	5.408	Red	6.455	-4.536	4.943	3.630	1.262	4.051
White	4.752	-5.097	3.053	3.914	1.477	4.406	White	4.383	-5.228	2.640	3.522	1.112	3.893
Total	29.620	-26.325	20.845	20.232	6.798	22.498	Total	27.450	-22.802	19.849	19.152	5.787	21.081
Round 3							Round 3						
Black	5.625	-4.619	4.085	4.054	1.143	4.435	Black	6.194	-3.813	4.923	3.909	581	4.103
Blue	7.308	-6.260	5.221	3.814	1.395	4.279	Blue	5.456	-2.990	4.459	3.553	800	3.820
Pink	6.556	-4.204	5.155	4.524	1.068	4.880	Pink	6.022	-3.793	4.758	4.102	570	4.291
Red	7.097	-6.453	4.946	4.763	1.743	5.344	Red	7.081	-4.437	5.602	3.804	863	4.092
White	6.463	-5.936	4.484	4.170	1.836	4.782	White	6.216	-4.414	4.745	3.918	1.120	4.291
Total	33.049	-27.472	23.892	21.325	7.185	23.720	Total	30.969	-19.447	24.487	19.286	3.934	20.597
Round 4							Round 4						
Black	5.588	-5.216	3.849	4.911	2.200	5.644	Black	6.309	-3.813	5.038	3.793	581	3.987
Blue	7.308	-6.260	5.221	4.745	2.013	5.416	Blue	5.456	-2.990	4.459	3.649	724	3.890
Pink	5.628	-4.385	4.166	5.230	1.446	5.712	Pink	6.022	-3.793	4.758	3.847	540	4.027
Red	7.864	-6.807	5.595	5.550	2.207	6.286	Red	7.081	-4.437	5.602	3.453	1.068	3.809
White	6.720	-6.560	4.533	5.512	2.607	6.381	White	5.299	-4.012	3.962	3.313	939	3.626
Total	33.108	-29.228	23.365	25.948	10.473	29.439	Total	30.167	-19.045	23.819	18.055	3.852	19.339

	R1	R2	R3	R4	R5	R6	R7	min	max	avg
Profit										
А	45.494	42.688	51.701					42.688	51.701	46.628
В	44.809	36.496	43.760	44.957				36.496	44.957	42.506
С	49.091	48.140	46.788	48.969				46.788	49.091	48.247
D	45.042	32.302	34.197					32.302	45.042	37.180
Е	40.441	39.388	39.698	41.644	41.941	43.447	50.001	39.388	50.001	42.366
F	47.580	43.343	47.612	52.804				43.343	52.804	47.835
G	49.072	40.930	45.084	43.158				40.930	49.072	44.561
TTL										
А	32.442	25.155	31.662					25.155	32.442	29.753
В	36.651	24.032	25.561	24.840				24.032	36.651	27.771
С	32.369	29.603	26.468	25.830				25.830	32.369	28.568
D	25.704	15.321	16.845					15.321	25.704	19.290
Е	22.146	19.423	18.672	19.041	19.422	20.357	25.562	18.672	25.562	20.661
F	31.990	22.498	23.720	29.439				22.498	31.990	26.912
G	40.851	21.081	20.597	19.339				19.339	40.851	25.467
Utility										
A	13.052	17.533	20.039					13.052	20.039	16.875
В	8.158	12.464	18.199	20.118				8.158	20.118	14.735
С	16.722	18.537	20.320	23.139				16.722	23.139	19.679
D	19.338	16.981	17.352					16.981	19.338	17.890
Е	18.295	19.964	21.026	22.603	22.518	23.090	24.439	18.295	24.439	21.705
F	15.591	20.845	23.892	23.365				15.591	23.892	20.923
G	8.221	19.849	24.487	23.819				8.221	24.487	19.094

Table 3.3 contains a summarised overview of the previous detailed session outcome listing per player. The columns R1 to R7 represent the rounds of the game. The profit and utility are the total session values in thousands of euros, the ttl is the session total in hours.

Table 3.3: Outcomes per objective summed over all players in the session per round and summarised over all rounds.

3.3 Strategy Scores

Session A G _p G _t G _r Session B G _p G _t G _r Session C G _p G _t G _r Session D G _p G _t G _r Black 0.786 0.143 0.071 Black 0.500 0.333 0.167 Black 0.020 0.000 Black 0.220 0.250 0.250 0.250 0.500 0.500 0.333 0.167 Black 0.020 0.000 Black 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.000 <td< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></td<>																
Round 1 Round 1 Round 1 Round 1 Round 1 Round 1 Black 0.786 0.143 0.071 Black 0.500 0.333 0.167 Black 1.000 0.000 0.000 Black 0.250 0.520 0.500 0.292 0.208 arg. 0.647 0.206 0.147 arg. 0.585 0.181 0.230 0.571 0.513 0.184 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400	Session A	G_p	G_t	G_r	Session B	G_p	G_t	G_r	Session C	G_p	G_t	G_r	Session D	G_p	G_t	G_r
Black 0.786 0.143 0.071 Black 0.500 0.333 0.167 Black 1.000 0.000 Black 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.250 0.252 0.125 Blue 0.625 0.250 0.125 Blue 0.625 0.250 0.125 Blue 0.625 0.250 0.125 Blue 0.625 0.255 0.125 Blue 0.625 0.255 0.125 D.000 0.000 Black 0.71 0.214 Blue 0.625 0.225 D.125 D.10 D.10 D.10 D.10 D.10 D.10 D.10 D.10	Round 1															
Blac 0.563 0.188 0.250 Blue 0.714 0.714 0.214 Blue 0.625 0.250 D.125 Blue 0.625 0.220 Name 0.339 0.338 0.333 0.33	Black	0.786	0.143	0.071	Black	0.500	0.333	0.167	Black	1.000	0.000	0.000	Black	0.250	0.250	0.500
Pink 0.222 0.389 0.389 0.389 0.389 0.222 Pink 0.333 0.343 0.000 0.000 0	Blue	0.563	0.188	0.250	Blue	0.714	0.071	0.214	Blue	0.625	0.250	0.125	Blue	0.625	0.250	0.125
Red 0.786 0.143 0.071 Red 0.786 0.143 0.071 Red 0.222 0.389 0.389 Red 1.000 0.000 </td <td>Pink</td> <td>0.222</td> <td>0.389</td> <td>0.389</td> <td>Pink</td> <td>0.500</td> <td>0.313</td> <td>0.188</td> <td>Pink</td> <td>0.389</td> <td>0.389</td> <td>0.222</td> <td>Pink</td> <td>0.333</td> <td>0.333</td> <td>0.333</td>	Pink	0.222	0.389	0.389	Pink	0.500	0.313	0.188	Pink	0.389	0.389	0.222	Pink	0.333	0.333	0.333
White 0.625 0.250 0.125 White 0.000 0.600 White 1.000 0.000 0.000 White 0.714 0.711 0.214 avg. 0.596 0.222 0.181 avg. 0.500 0.292 0.208 avg. 0.647 0.206 0.147 avg. 0.585 0.181 0.235 Black 0.786 0.143 0.071 Black 0.400 0.200 Black 1.000 0.000 0.000 Black 0.250 0.250 0.250 0.500 0.500 0.501 0.505 0.180 0.250 0.125 Blue 0.625 0.500 0.133 0.188 Pink 0.389 0.389 0.222 Pink 0.200 0.300 0.400 0.400 0.000	Red	0.786	0.143	0.071	Red	0.786	0.143	0.071	Red	0.222	0.389	0.389	Red	1.000	0.000	0.000
avg. 0.596 0.222 0.181 avg. 0.500 0.292 0.208 avg. 0.647 0.206 0.147 avg. 0.585 0.181 0.235 Round 2 Round 3 Black 0.430 0.701 0.214 Blue 0.625 0.250 0.125 Black 0.200 Black 1.000 0.000 0.000 Black 0.230 0.212 Black 0.250 0.200 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400 0.400	White	0.625	0.250	0.125	White	0.000	0.600	0.400	White	1.000	0.000	0.000	White	0.714	0.071	0.214
Round 2 Round 3 Round 3 Round 3 Round 4 Round 5 Round 5 <t< td=""><td>avg.</td><td>0.596</td><td>0.222</td><td>0.181</td><td>avg.</td><td>0.500</td><td>0.292</td><td>0.208</td><td>avg.</td><td>0.647</td><td>0.206</td><td>0.147</td><td>avg.</td><td>0.585</td><td>0.181</td><td>0.235</td></t<>	avg.	0.596	0.222	0.181	avg.	0.500	0.292	0.208	avg.	0.647	0.206	0.147	avg.	0.585	0.181	0.235
Black 0.786 0.143 0.071 Black 0.400 0.200 Black 1.000 0.000 Black 0.250 0.250 0.250 0.500 Blue 0.786 0.143 0.071 Pink 0.500 0.313 0.188 Pink 0.389 0.222 Pink 0.200 0.400 0.400 0.400 0.400 0.200 Blue 0.625 0.250 0.125 Blue 0.625 0.250 0.125 Pink 0.200 0.300 0.400 0.400 0.200 Seed 0.400 0.400 0.200 White 0.625 0.250 0.125 White 0.000 0.000 Avg. 0.647 0.200 Mint 0.000	Round 2															
Blue 0.563 0.188 0.250 Blue 0.714 0.071 0.214 Blue 0.625 0.250 0.125 Blue 0.625 0.250 0.125 Pink 0.786 0.143 0.071 Pink 0.500 0.313 0.188 Pink 0.389 0.389 0.222 Pink 0.200 0.450 0.440 0.400	Black	0.786	0.143	0.071	Black	0.400	0.400	0.200	Black	1.000	0.000	0.000	Black	0.250	0.250	0.500
Pink Red 0.786 0.143 0.071 0.786 Pink 0.143 0.071 0.071 Pink Red 1.000 0.000 0.000 Red Red 0.389 0.389 0.389 Red 0.222 Pink 0.389 0.202 Pink Red 0.200 0.350 0.450 White 0.625 0.250 0.125 White 0.000 0.600 0.400 White 1.000 0.000	Blue	0.563	0.188	0.250	Blue	0.714	0.071	0.214	Blue	0.625	0.250	0.125	Blue	0.625	0.250	0.125
Red White 0.786 0.143 0.071 Red White 1.000 0.000 0.000 Red White 0.222 0.389 0.389 Red White 0.400 0.400 0.200 avg. 0.709 0.173 0.118 avg. 0.523 0.277 0.200 avg. 0.647 0.206 0.147 avg. 0.295 0.370 0.335 Round 3 None	Pink	0.786	0.143	0.071	Pink	0.500	0.313	0.188	Pink	0.389	0.389	0.222	Pink	0.200	0.350	0.450
White 0.625 0.250 0.125 White 0.000 0.600 0.400 White 1.000 0.000 0.000 White 0.000 0.600 0.400 avg. 0.709 0.173 0.118 avg. 0.523 0.277 0.200 avg. 0.647 0.206 0.147 avg. 0.295 0.370 0.335 Bound 3 Black 0.786 0.143 0.071 Black 0.400 0.400 0.200 Black 0.714 0.071 0.214 Black 0.250 0.250 0.500 0.500 0.250 D.500 <thd.500< th=""> D.500 D.500<</thd.500<>	Red	0.786	0.143	0.071	Red	1.000	0.000	0.000	Red	0.222	0.389	0.389	Red	0.400	0.400	0.200
avg. 0.709 0.173 0.118 avg. 0.523 0.277 0.200 avg. 0.647 0.206 0.147 avg. 0.295 0.370 0.335 Round 3 Black 0.786 0.143 0.071 Black 0.400 0.400 0.200 Black 0.714 0.071 0.214 Black 0.625 0.250 0.500 0.500 Pink 0.786 0.143 0.071 Black 0.400 0.000 0.000 Blue 1.000 0.000 0.000 Blue 0.625 0.250 0.125 Pink 0.625 0.250 0.125 Pink 0.200 0.335 0.450 White 0.563 0.188 0.250 Black 0.771 Pink 0.625 0.278 0.444 Red 0.500 0.335 0.450 avg. 0.739 0.132 0.129 0.637 0.229 0.134 avg. 0.723 0.120 0.157 avg. 0.335 0.347 0.318 Black 0.739 0.132 0.129 0.637 0	White	0.625	0.250	0.125	White	0.000	0.600	0.400	White	1.000	0.000	0.000	White	0.000	0.600	0.400
Round 3 Round 3 Round 3 Round 3 Black 0.786 0.143 0.071 Black 0.400 0.200 Black 0.714 0.071 0.214 Black 0.250 0.500 0.500 Disc 0.000 0.000 Blue 1.000 0.000 0.000 Blue 1.000 0.000 Blue 1.000 0.000 0.000 Blue 0.000 0.000 Blue 1.000 0.000 0.000 Blue 0.000 0.000 Blue 0.000 0.000 Blue 0.000 0.00	avg.	0.709	0.173	0.118	avg.	0.523	0.277	0.200	avg.	0.647	0.206	0.147	avg.	0.295	0.370	0.335
Black 0.786 0.143 0.071 Black 0.400 0.400 0.200 Black 0.714 0.071 0.214 Black 0.250 0.500 Blue 0.563 0.188 0.250 Blue 1.000 0.000 Blue 1.000 0.000 Blue 1.000 0.000 Blue 0.625 0.250 0.125 Pink 0.786 0.143 0.071 Red 1.000 0.000 Red 0.278 0.244 Red 0.200 0.333 0.167 White 0.563 0.188 0.250 Mite 0.000 0.000 0.000 White 0.000 0.000 White 0.000 0.000 White 0.200 0.333 0.167 avg. 0.739 0.132 0.129 0.637 0.229 0.134 avg. 0.723 0.120 0.157 avg. 0.335 0.347 0.318 Black 0.400 0.400 0.200 0.200 Black	Round 3															
Blue 0.563 0.188 0.250 Blue 1.000 0.000 0.000 Blue 1.000 0.	Black	0.786	0.143	0.071	Black	0.400	0.400	0.200	Black	0.714	0.071	0.214	Black	0.250	0.250	0.500
Pink Red 0.786 0.143 0.071 Red Pink 1.000 0.078 0.143 0.071 Red Pink Red 0.625 0.250 0.125 Pink Red 0.200 0.350 0.450 white 0.563 0.188 0.250 White 0.000 0.000 White 0.000 0.000 White 0.000 0.001 0.001 0.011 0.214 0.214 0.071 0.214 0.07	Blue	0.563	0.188	0.250	Blue	1.000	0.000	0.000	Blue	1.000	0.000	0.000	Blue	0.625	0.250	0.125
Red White 1.000 0.000 0.000 White Red 0.000 1.000 0.000 White Red 0.000 0.000 Red White 0.000 0.000 White Red 0.000 0.000 Red White 0.000 0.000 Red White 0.000 0.000 Red White 0.000 0.000 White 0.000 0.000 White 0.000 0.000 White 0.000 0.000 White 0.000 0.000 0.000 White 0.100 0.550 0.350 0.350 0.350 0.335 0.347 0.318 avg. 0.739 0.132 0.129 0.132 0.129 0.440 avg. 0.723 0.120 0.157 avg. 0.335 0.347 0.318 Round 4 Red 0.071 0.214 Round 4 Red 0.000 0.000 Red 0.071 0.214 Round 4 Red 0.000 Red 0.000 Red 0.071 <th< td=""><td>Pink</td><td>0.786</td><td>0.143</td><td>0.071</td><td>Pink</td><td>0.786</td><td>0.143</td><td>0.071</td><td>Pink</td><td>0.625</td><td>0.250</td><td>0.125</td><td>Pink</td><td>0.200</td><td>0.350</td><td>0.450</td></th<>	Pink	0.786	0.143	0.071	Pink	0.786	0.143	0.071	Pink	0.625	0.250	0.125	Pink	0.200	0.350	0.450
White 0.563 0.188 0.250 White 0.000 0.600 0.400 White 1.000 0.000 0.000 White 0.100 0.550 0.350 avg. 0.739 0.132 0.129 0.637 0.229 0.134 avg. 0.723 0.120 0.157 avg. 0.335 0.347 0.318 Round 4 Black 0.400 0.400 0.200 Black 0.714 0.071 0.214 Blue 1.000 0.000 0.000 Blue 0.714 0.071 0.214 Pink 0.786 0.143 0.071 Pink 0.786 0.143 0.071 Red 1.000 0.000 Red 0.278 0.278 0.244 White 0.000 0.600 0.400 White 1.000 0.000 0.000 avg. 0.637 0.229 0.134 avg. 0.698 0.113 0.189	Red	1.000	0.000	0.000	Red	1.000	0.000	0.000	Red	0.278	0.278	0.444	Red	0.500	0.333	0.167
avg. 0.739 0.132 0.129 avg. 0.637 0.229 0.134 avg. 0.723 0.120 0.157 avg. 0.335 0.347 0.318 Round 4 Round 4 Black 0.400 0.200 Black 0.714 0.071 0.214 Blue 1.000 0.000 0.000 Blue 0.714 0.071 0.214 Pink 0.786 0.143 0.071 Pink 0.786 0.143 0.071 Red 1.000 0.000 Red 0.278 0.278 0.444 White 0.000 0.600 0.400 White 1.000 0.000 avg. 0.637 0.229 0.134 avg. 0.698 0.113 0.189	White	0.563	0.188	0.250	White	0.000	0.600	0.400	White	1.000	0.000	0.000	White	0.100	0.550	0.350
Round 4Round 4Black0.4000.4000.200Black0.7140.0710.214Blue1.0000.0000.000Blue0.7140.0710.214Pink0.7860.1430.071Pink0.7860.1430.071Red1.0000.000Red0.2780.2780.444White0.0000.6000.400White1.0000.0000.000avg.0.6370.2290.134avg.0.6980.1130.189	avg.	0.739	0.132	0.129	avg.	0.637	0.229	0.134	avg.	0.723	0.120	0.157	avg.	0.335	0.347	0.318
Black 0.400 0.400 0.200 Black 0.714 0.071 0.214 Blue 1.000 0.000 0.000 Blue 0.714 0.071 0.214 Pink 0.786 0.143 0.071 Pink 0.786 0.143 0.071 Red 1.000 0.000 0.000 Red 0.278 0.278 0.444 White 0.000 0.600 White 1.000 0.000 0.000 avg. 0.637 0.229 0.134 avg. 0.698 0.113 0.189					Round 4				Round 4							
Blue1.0000.0000.000Blue0.7140.0710.214Pink0.7860.1430.071Pink0.7860.1430.071Red1.0000.000Red0.2780.2780.444White0.0000.6000.400White1.0000.0000.000avg.0.6370.2290.134avg.0.6980.1130.189					Black	0.400	0.400	0.200	Black	0.714	0.071	0.214				
Pink 0.786 0.143 0.071 Pink 0.786 0.143 0.071 Red 1.000 0.000 0.000 Red 0.278 0.278 0.444 White 0.000 0.600 0.400 White 1.000 0.000 0.000 avg. 0.637 0.229 0.134 avg. 0.698 0.113 0.189					Blue	1.000	0.000	0.000	Blue	0.714	0.071	0.214				
Red 1.000 0.000 0.000 Red 0.278 0.278 0.444 White 0.000 0.600 0.400 White 1.000 0.000 0.000 avg. 0.637 0.229 0.134 avg. 0.698 0.113 0.189					Pink	0.786	0.143	0.071	Pink	0.786	0.143	0.071				
White 0.000 0.600 0.400 White 1.000 0.000 0.000 avg. 0.637 0.229 0.134 avg. 0.698 0.113 0.189					Red	1.000	0.000	0.000	Red	0.278	0.278	0.444				
avg. 0.637 0.229 0.134 avg. 0.698 0.113 0.189					White	0.000	0.600	0.400	White	1.000	0.000	0.000				
					avg.	0.637	0.229	0.134	avg.	0.698	0.113	0.189				

Session E	G_p	G_t	G_r	Session F	G_p	G_t	G_r	Session G	G_p	G_t	G_r
Round 1				Round 1				Round 1			
Black	0.563	0.188	0.250	Black	0.563	0.188	0.250	Black	1.000	0.000	0.000
Blue	0.300	0.300	0.400	Blue	0.625	0.250	0.125	Blue	0.625	0.250	0.125
Pink	0.375	0.375	0.250	Pink	0.438	0.250	0.313	Pink	1.000	0.000	0.000
Red	0.333	0.333	0.333	Red	0.643	0.214	0.143	Red	0.714	0.071	0.214
White	0.389	0.389	0.222	White	0.714	0.071	0.214	White	0.350	0.350	0.300
avg.	0.392	0.317	0.291	avg.	0.596	0.195	0.209	avg.	0.738	0.134	0.128
Round 2				Round 2				Round 2			
Black	0.563	0.188	0.250	Black	0.563	0.188	0.250	Black	0.786	0.143	0.071
Blue	0.300	0.300	0.400	Blue	0.625	0.250	0.125	Blue	0.444	0.278	0.278
Pink	0.375	0.375	0.250	Pink	0.563	0.188	0.250	Pink	0.563	0.188	0.250
Red	0.389	0.389	0.222	Red	0.643	0.214	0.143	Red	0.563	0.188	0.250
White	0.389	0.389	0.222	White	0.563	0.188	0.250	White	0.350	0.350	0.300
avg.	0.403	0.328	0.269	avg.	0.591	0.205	0.204	avg.	0.541	0.229	0.230
Round 3				Round 3				Round 3			
Black	0 563	0 188	0.250	Black	0 563	0 188	0.250	Black	0 563	0 188	0.250
Blue	0.300	0.300	0.400	Blue	0.625	0.250	0.125	Blue	0.444	0.278	0.278
Pink	0 389	0 389	0.222	Pink	0.563	0.188	0.250	Pink	0.563	0.188	0.250
Red	0.389	0.389	0.222	Red	0.643	0.214	0.143	Red	0.563	0 188	0.250
White	0.389	0.389	0.222	White	0.786	0.143	0.071	White	0.563	0.188	0.250
avg.	0.406	0.331	0.263	avg.	0.636	0.196	0.168	avg.	0.539	0.206	0.256
Round 4				Round 4				Round 4			
Black	0.563	0.188	0.250	Black	0.714	0.071	0.214	Black	0.563	0.188	0.250
Blue	0.444	0.278	0.278	Blue	0.625	0.250	0.125	Blue	0.444	0.278	0.278
Pink	0.389	0.389	0.222	Pink	0.563	0.188	0.250	Pink	0.563	0.188	0.250
Red	0.500	0.313	0.188	Red	1.000	0.000	0.000	Red	0.563	0.188	0.250
White	0.389	0.389	0.222	White	1.000	0.000	0.000	White	0.444	0.278	0.278
avg.	0.457	0.311	0.232	avg.	0.780	0.102	0.118	avg.	0.515	0.224	0.261
Round 5											
Black	0 563	0 188	0.250								
Blue	0.444	0.278	0.278								
Pink	0 389	0.389	0.222								
Red	0.500	0.313	0.188								
White	0.389	0.389	0.222								
avg.	0.457	0.311	0.232								
Round 6											
Black	0 563	0.188	0.250								
Blue	0.303	0.279	0.278								
Diuc	0.444	0.278	0.270								

Diac	0.111	0.270	0.270
Pink	0.389	0.389	0.222
Red	0.500	0.313	0.188
White	0.389	0.389	0.222
avg.	0.504	0.283	0.213
Round 7			
Black	0.563	0.188	0.250
Blue	0.563	0.188	0.250
Pink	0.389	0.389	0.222
Red	1.000	0.000	0.000
White	0.389	0.389	0.222
avg.	0.628	0.203	0.169

	R1	R2	R3	R4	R5	R6	R7	min	max	avg
Profit										
А	0.596	0.709	0.739					0.596	0.739	0.681
В	0.500	0.523	0.637	0.637				0.500	0.637	0.574
С	0.647	0.647	0.723	0.698				0.647	0.723	0.679
D	0.585	0.295	0.335					0.295	0.585	0.405
Е	0.392	0.403	0.406	0.457	0.457	0.504	0.628	0.392	0.628	0.464
F	0.596	0.591	0.636	0.780				0.591	0.780	0.651
G	0.738	0.541	0.539	0.515				0.515	0.738	0.583
TTL										
А	0.222	0.173	0.132					0.132	0.222	0.176
В	0.292	0.277	0.229	0.229				0.229	0.292	0.256
С	0.206	0.206	0.120	0.113				0.113	0.206	0.161
D	0.181	0.370	0.347					0.181	0.370	0.299
Е	0.317	0.328	0.331	0.311	0.311	0.283	0.203	0.203	0.331	0.298
F	0.195	0.205	0.196	0.102				0.102	0.205	0.175
G	0.134	0.229	0.206	0.224				0.134	0.229	0.198
Risk aversion										
А	0.181	0.118	0.129					0.118	0.181	0.143
В	0.208	0.200	0.134	0.134				0.134	0.208	0.169
С	0.147	0.147	0.157	0.189				0.147	0.189	0.160
D	0.235	0.335	0.318					0.235	0.335	0.296
Е	0.291	0.269	0.263	0.232	0.232	0.213	0.169	0.169	0.291	0.238
F	0.209	0.204	0.168	0.118				0.118	0.209	0.175
G	0.128	0.230	0.256	0.261				0.128	0.261	0.219

And, as with the outcomes, Table 3.4 summarises the strategy scores per session over all rounds of the game.

Table 3.4: Strategy profile scores objective averaged over all players in the session per round and summarised over all rounds.

4 | Validation of the game model

For completeness, the correctness of the game model is expressed as an additional hypothesis, describing that the actions of the game have the intended effect on the outcome. This hypothesis is subsequently tested against the measurements obtained from the gaming sessions of the previous chapter to establish that indeed the actions of the game have their intended impact on the game outcomes. Put differently, higher ttl strategy scores should lead to lower ttl in the outcome of the game, and similarly for the other objectives. The correctness hypothesis is formulated as:

Hypothesis 1 (Action Consistency). *The actions (maintenance alternatives) in the game are label consistent to their intended impact on the game outcomes for all of the objectives (a) profit, (b) ttl and (c) risk aversion.*



Figure 4.1: The impact of actions on the outcome of the game: (a) and (b) show the profit and ttl strategy scores respectively versus the total expected revenue and ttl obtained from joint plans, and (c) shows the risk-aversion strategy score versus the worst case revenue loss and ttl increase.

Figure 4.1 shows the total expected revenue and ttl of that results from each joint plan submitted at the end of a planning round versus the corresponding strategy scores (Appendix 2) in all three objectives: (a) revenue, (b) ttl and (c) risk aversion. From figures 4.1(a) and 4.1(b) a clear relation can be observed between the action choices and the effect on the outcome: a higher profit strategy score leads higher revenue and, similarly, a higher ttl strategy score is paired with a reduction in ttl. The few outliers in the 28-35K range all correspond to joint plans submitted in the initial planning round. As players do not coordinate yet in this round, they are to be expected to be much worse in terms of ttl. Coincidentally, these outliers provide a good illustration of the significance of coordination in a self-regulating network. Finally, Figure 4.1(c) shows 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 strong correlation can be observed, i.e. a higher risk aversion score results in a lower worst-case revenue loss and lower worst-case ttl increase.

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