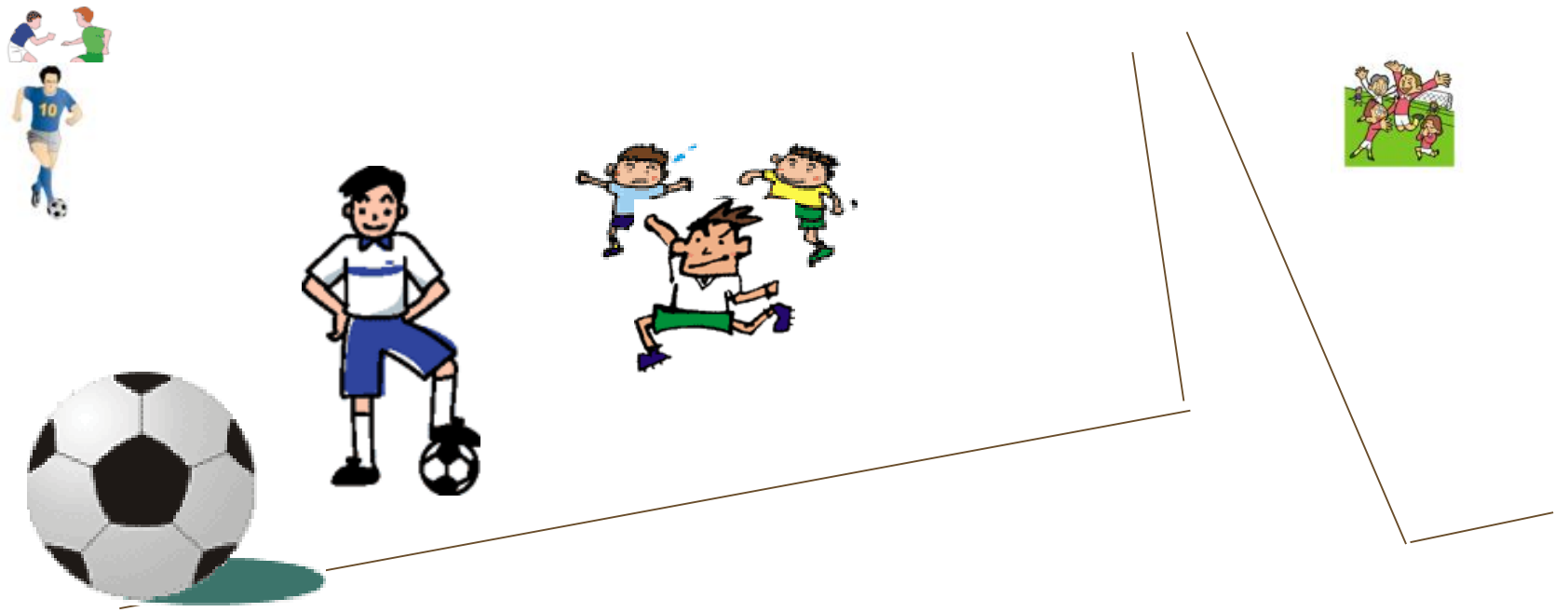
Analysing the Effect of a Change of Transition Probabilities Related to Possession on Scoring a Goal in a Football Match



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Outline

1. Introduction

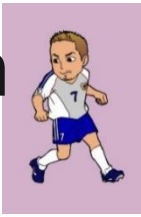
Modelling an association football match is a topic of interest for evaluating teams' characteristics, predicting the outcome of a match, or analysing optimal tactical changes.

e.g. Maher (1982), Lee (1997), Dixon and Coles (1997), Dixon and Robinson (1998), Hirotsu and Wright (2003) Liu and Hohmann (2013), Rudd (2011), Yam (2019)

Hirotsu et al.(2017) used Markov process model considering the location of the ball on the pitch, by dividing the pitch up to 9 areas.

We here use the model of Hirotsu et al.(2017) to analyze the effect of a change of transition probabilities related to possession on scoring a goal or winning a match.

2. Markov Process Model of a Football Match



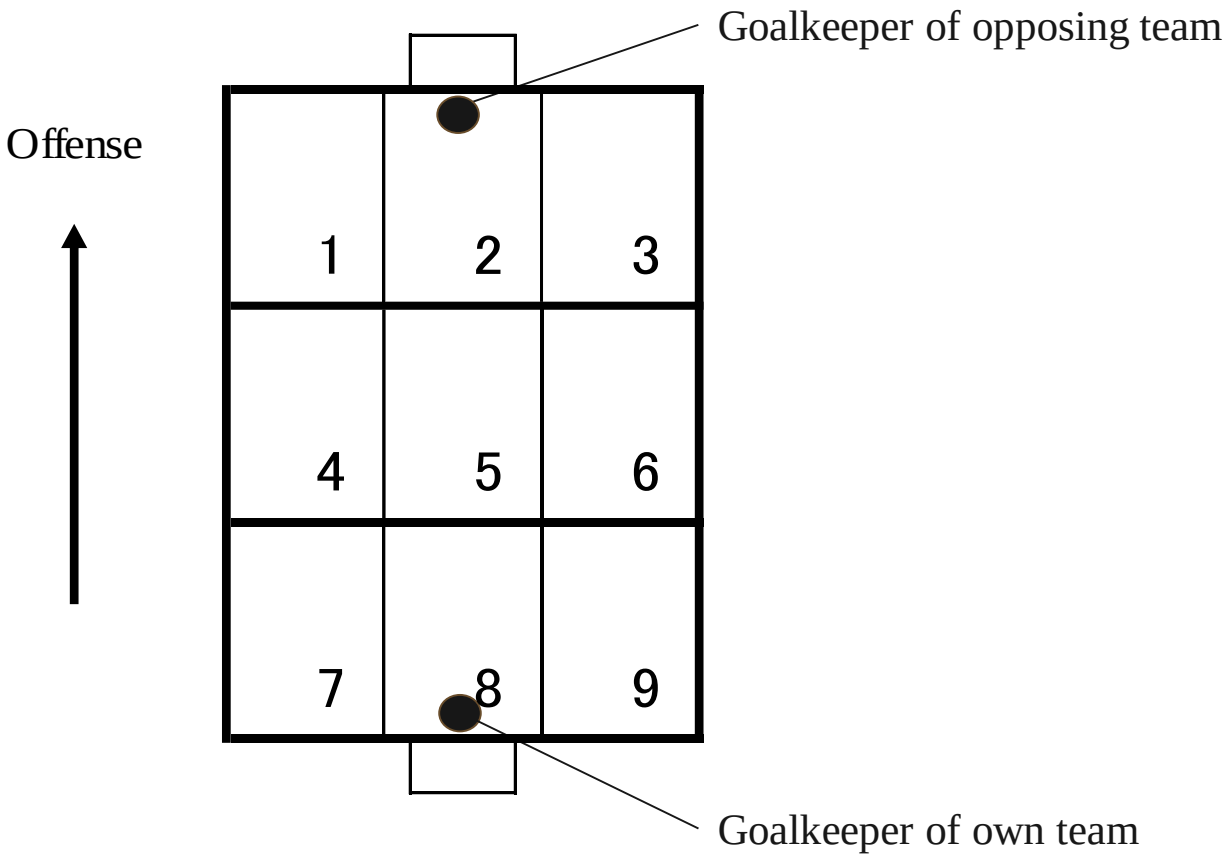


Figure. The areas on the pitch.

2. Markov process model of a football match

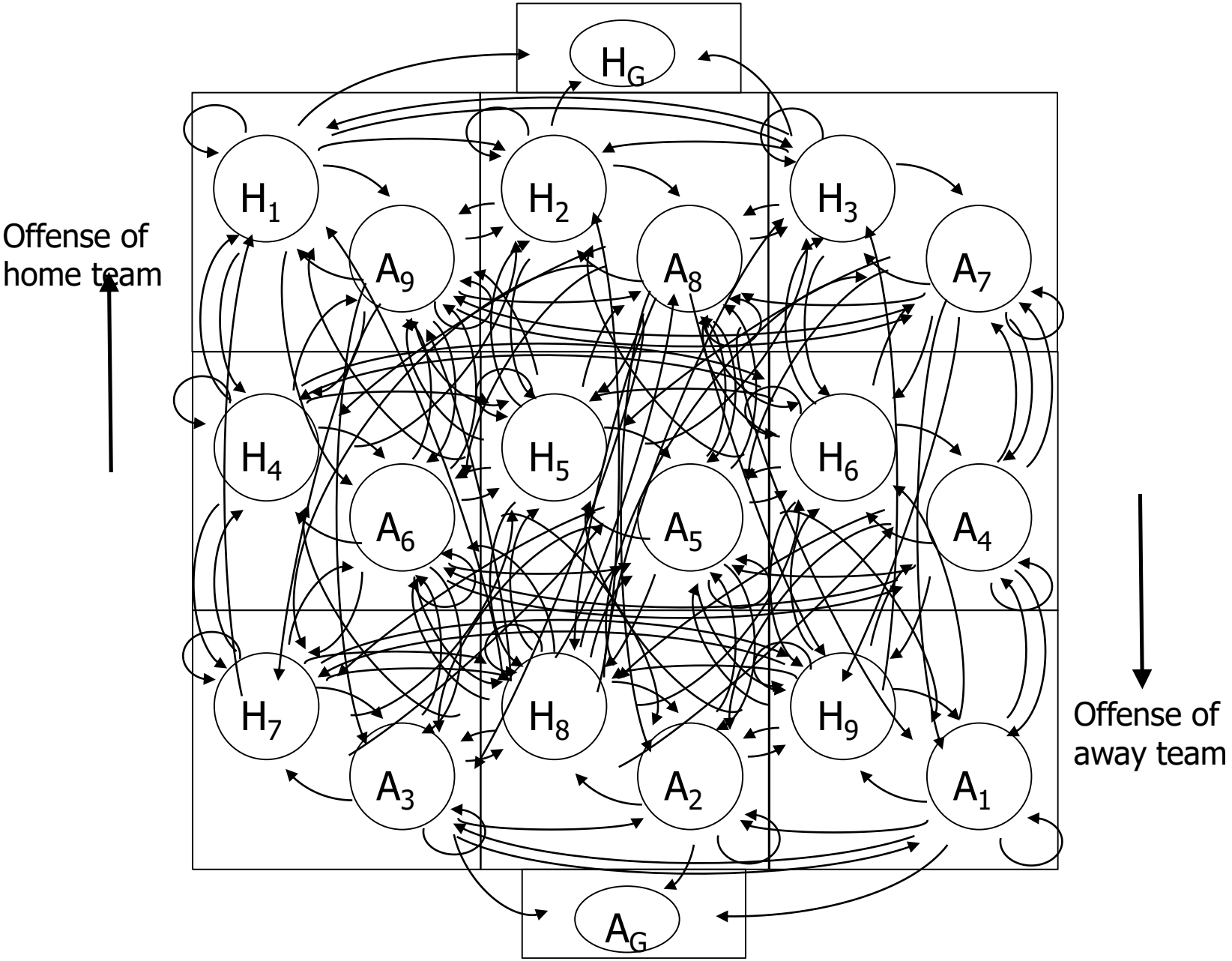


Figure. Graphical Image of the Markov process model

2. Markov Process Model of a Football Match

State H_G: Home team scores a goal;

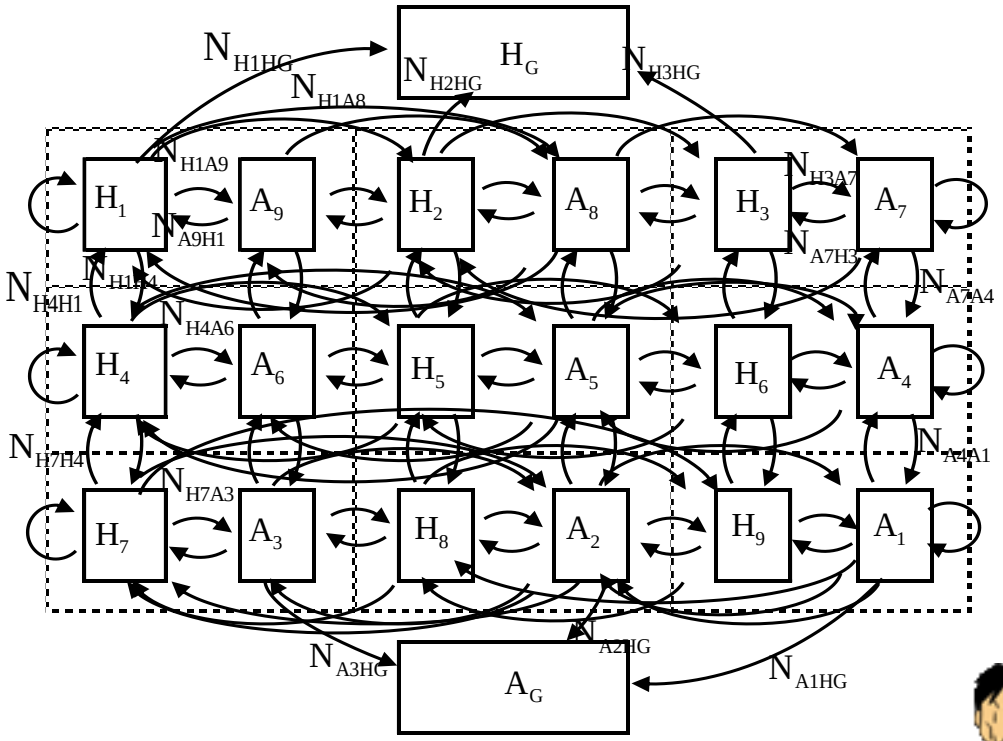
State H_I: Home team is in possession of the ball and the ball is located in the "I" area (I=1,…, 9);

State A_I: Away team is in possession of the ball and the ball is located in the "I" area (I=1,…, 9).

State A_G: Away team scores a goal.

N_{ij} is the total number of transitions from state i to state j in a game (i,j=H_1,H_2,…,A_1)

T_i is the total time for which the game is in state i in a game (i=H_1,H_2,…,A_1)



※All arrows are not presented.

2. Markov Process Model of a Football Match

State H_G: Home team scores a goal;

State H_I: Home team is in possession of the ball and the ball is located in the "I" area (I=1,…, 9);

State A_I: Away team is in possession of the ball and the ball is located in the "I" area (I=1,…, 9).

State A_G: Away team scores a goal.

$N_{H_2H_G}$:Number of goals by home team from 2

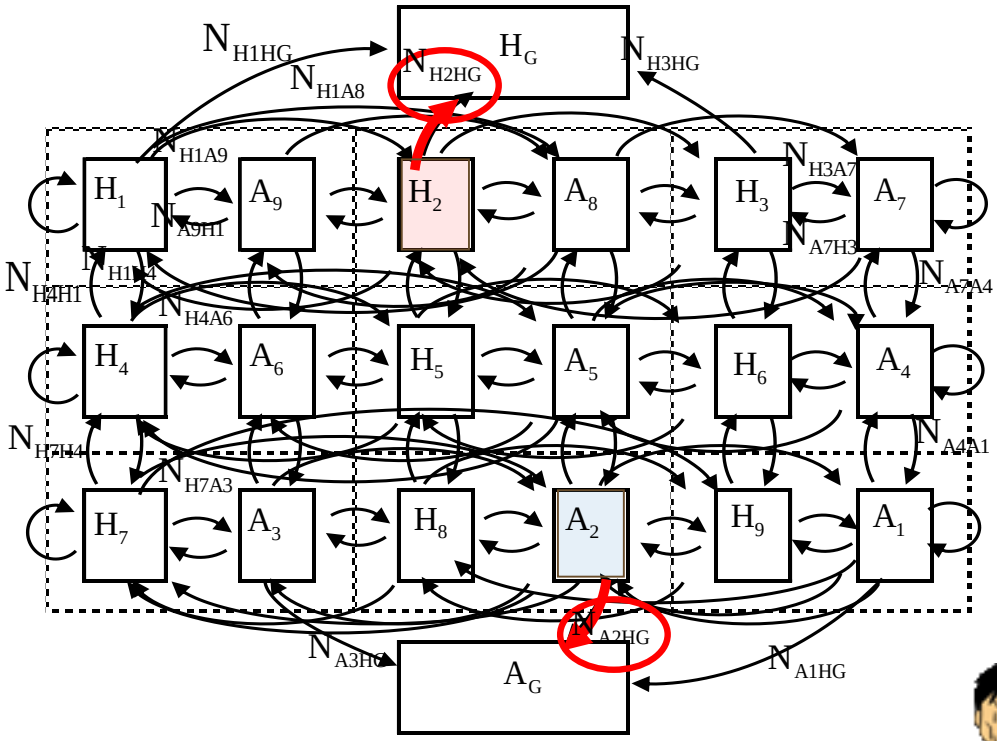
$N_{A_2A_G}$:Number of goals by away team from 2

$N_{H_1A_9}$:Number of transition of possession in 1 (Home team->Away team)

$N_{H_5H_2}$:Number of transition from 5 to 2 by keeping the possession by home team (5-> 2)

T_{H_2} : Possession time of home team in 2

T_{A_2} : Possession time of away team in 2



※All arrows are not presented.

2. Markov Process Model of a Football Match

Estimation of transition rates

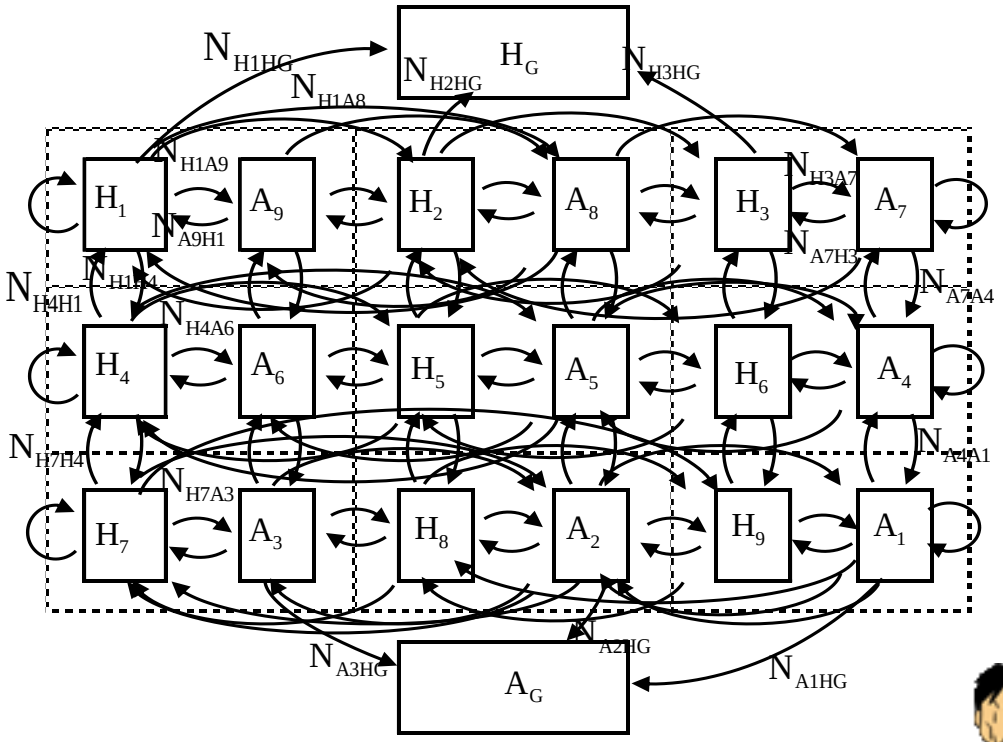
If the total numbers of transitions and the time spent in each state are all observed, the transition rates can be estimated:

Transition rates:

$a_{iH_G} = N_{iH_G} / T_i \quad (i=H_1,H_2,\ldots,H_6)$

$a_{ij} = N_{ij} / T_i \quad (i,j=H_1,H_2,\ldots,A_1)$

$a_{iA_G} = N_{iA_G} / T_i \quad (i=A_1,A_2,\ldots,A_6)$



2. Markov Process Model of a Football Match

Definition of transition probabilities

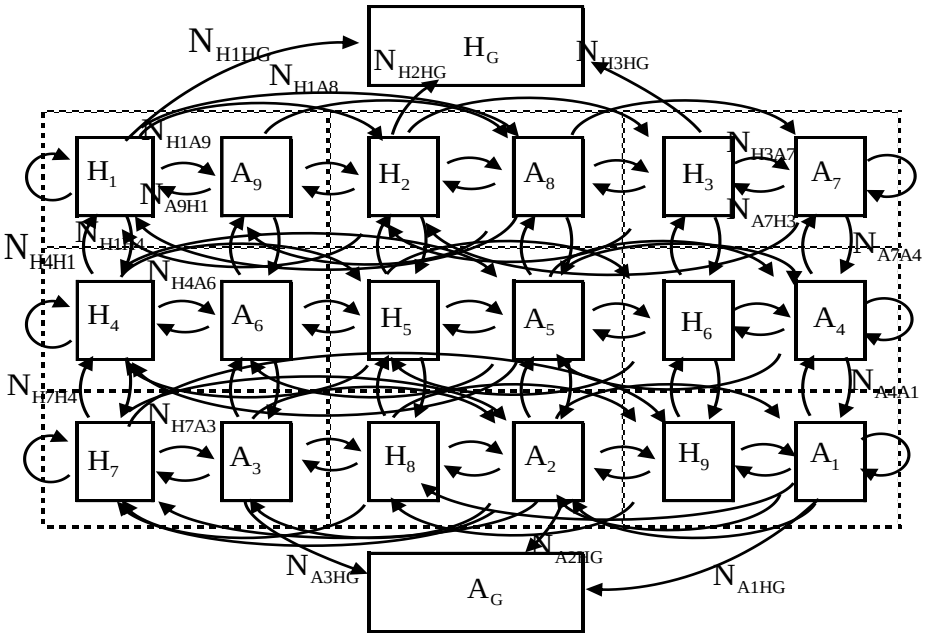
Transition	Probability	Remarks
$i \rightarrow H_G$	$a_{iHG}\,dt$	Transition from possession to scoring a goal for home team from state i (i=H_1,H_2,…,H_6)
$i \rightarrow j$	$a_{ij}\,dt$	Transition from state i to state j (i,j=H_1,H_2,…,A_1)
$i \rightarrow A_G$	$a_{iHG}\,dt$	Transition from possession to scoring a goal for away team from state i (i=A_1,A_2,…,A_6)

Transition rates:

$a_{iH_G} = N_{iH_G}/T_i \quad (i=H_1,H_2,\ldots,H_6)$

$a_{ij} = N_{ij}/T_i \quad (i,j=H_1,H_2,\ldots,A_1)$

$a_{iA_G} = N_{iA_G}/T_i \quad (i=A_1,A_2,\ldots,A_6)$



2. Markov Process Model of a Football Match

Calculation of probability of staying state i

$\pi_i(t)$: Probability of staying state i at a time t after the kick off (i = $H_1, H_2, \ldots, A_1$):

$$\pi_{H_1}(t+dt) = \pi_{H_2}(t)\cdot a_{H_2H_1}dt + \pi_{H_3}(t)\cdot a_{H_3H_1}dt + \cdots + \pi_{A_1}(t)\cdot a_{A_1H_1}dt + \pi_{H_1}(n\,|\,t)\cdot\left\{1-(a_{H_2H_1}+a_{H_3H_1}+\cdots+a_{A_1H_1})dt\right\}$$

$$\pi_{H_2}(t+dt) = \pi_{H_1}(t)\cdot a_{H_1H_2}dt + \pi_{H_3}(t)\cdot a_{H_3H_2}dt + \cdots + \pi_{A_1}(t)\cdot a_{A_1H_2}dt + \pi_{H_2}(n\,|\,t)\cdot\left\{1-(a_{H_1H_2}+a_{H_3H_2}+\cdots+a_{A_1H_2})dt\right\}$$

… … …

$$\pi_{A_1}(t+dt) = \pi_{H_1}(t)\cdot a_{H_1A_1}dt + \pi_{H_2}(t)\cdot a_{H_2A_1}dt + \cdots + \pi_{A_2}(t)\cdot a_{A_2A_1}dt + \pi_{A_1}(n\,|\,t)\cdot\left\{1-(a_{H_1A_1}+a_{H_2A_1}+\cdots+a_{A_2A_1})dt\right\}$$

Initial condition (t = 0):

$\pi_i(0)$ =1 : i =H_5 (or A_5)

$\pi_i(0)$ = 0 : Otherwise

2. Markov Process Model of a Football Match

Calculation of probability of staying a state

$\pi_i(t)$: Probability of staying state *i* at a time t after the kick off ($i = H_1, H_2, \ldots, A_1$):

$$\frac{d}{dt}(\pi_{H1}(t) \quad \pi_{H2}(t) \quad \pi_{H3}(t) \quad \cdots \quad \pi_{A1}(t)) =$$

$$(\pi_{H1}(t) \quad \pi_{H2}(t) \quad \pi_{H3}(t) \quad \cdots \quad \pi_{A1}(t)) \begin{pmatrix} -a_{H2H1} - a_{H3H1} - & \blacksquare & & & \\ a_{H2H1} & -a_{H1H2} - a_{H3H2} - \cdots - a_{A1H2} & a_{H2H3} & \cdots & a_{H2A1} \\ a_{H3H1} & a_{H3H2} & -a_{H1H3} - a_{H2H3} - \cdots - a_{A1H3} & \cdots & a_{H3A1} \\ & \blacksquare & & & \\ a_{A1H1} & a_{A1H2} & a_{A1H3} & \cdots & -a_{H1A1} - a_{H2A1} - \cdots - a_{A2A1} \end{pmatrix}$$

Initial condition ($t = 0$): H_5 (or A_5)

$$(\pi_{H1}(0) \quad \pi_{H2}(0) \quad \pi_{H3}(0) \quad \cdots \quad \pi_{A1}(0)) = (0 \quad 0 \quad \cdots \quad 0 \quad 1 \quad 0 \quad \cdots \quad 0)$$

2. Markov Process Model of a Football Match

Calculation of probability distribution of number of goals

$R_i(n|t)$: Probability of home team scoring n goals in the remaining time t minutes, starting from state i ($i = H_1, H_2, H_3, \ldots, A_1$):

$$R_{HG}(n \mid t+dt) = R_{A5}(n \mid t)$$

$$R_{H1}(n \mid t+dt) = R_{HG}(n-1 \mid t) \cdot a_{H1HG}dt + R_{H2}(n \mid t) \cdot a_{H1H2}dt + \cdots + R_{A1}(n \mid t) \cdot a_{H1A1}dt + R_{H1}(n \mid t) \cdot \{1 - a_{H1HG} - a_{H1H2} - \cdots - a_{H1A1})dt\}$$

$$R_{H2}(n \mid t+dt) = R_{H2HG}(n-1 \mid t) \cdot a_{H2G}dt + R_{H2H1}(n \mid t) \cdot a_{H2H1}dt + R_{H3}(n \mid t) \cdot a_{H2H3}dt + \cdots + R_{A1}(n \mid t) \cdot a_{H2A1}dt + R_{H2}(n \mid t) \cdot \{1 - a_{H2HG} - a_{H2H1} - a_{H2H3} - \cdots - a_{H1A2})dt\}$$

… … …

$$R_{AG}(n \mid t+dt) = R_{H5}(n \mid t)$$

Boundary conditions ($t = 0$):

$R_{H_1}(n|0) = R_{H_2}(n|0) = \ldots = R_{A_1}(n|0) = 1$: $n = 0$

$= 0$: Otherwise

2. Markov Process Model of a Football Match

Calculation of probability distribution of number of goals

$R_i(n|t)$: Probability of home team scoring n goals in the remaining time t minutes, starting from state i ($i = H_1, H_2, \ldots, A_1$):

$$\frac{d}{dt}\begin{pmatrix} R_{H1}(n|t) \\ R_{H2}(n|t) \\ R_{H3}(n|t) \\ \\ R_{A1}(n|t) \end{pmatrix} = \begin{pmatrix} -a_{H1HG} - a_{H1H2} - & & & & \\ a_{H2H1} & -a_{H2HG} - a_{H1H2} - \cdots - a_{H1A1} & a_{H2H3} & \cdots & a_{H2A1} \\ a_{H3H1} & a_{H3H2} & -a_{H3HG} - a_{H3H1} - \cdots - a_{H1A1} & \cdots & a_{H3A1} \\ & & & & \\ a_{A1H1} & a_{A1H1} & a_{A1H1} & \cdots & -a_{A1AG} - a_{A1H1} - \cdots - a_{A1A2} \end{pmatrix} \begin{pmatrix} R_{H2}(n|t) \\ R_{H3}(n|t) \\ \\ R_{A1}(n|t) \end{pmatrix}$$

$$+ \begin{pmatrix} \cdots & 0 & \cdots & a_{H1HG} & \cdots \\ \cdots & 0 & \cdots & a_{H2HG} & \cdots \\ \cdots & 0 & \cdots & a_{H3HG} & \cdots \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \cdots & 0 & \cdots & 0 & \cdots \end{pmatrix} \begin{pmatrix} \vdots \\ \vdots \\ \vdots \\ R_{A5}(n-1|t) \\ \vdots \end{pmatrix}$$

2. Markov Process Model of a Football Match

Calculation of probability of winning

$Wi(r|t)$: Probability of home team winning from a position of leading by r goals with time t remaining, starting from state i (i = $H_1, H_2, \ldots, A_1$):

$$W_{HG}(r \mid t+dt) = W_{A5}(r \mid t)$$

$$W_{H1}(r \mid t+dt) = W_{HG}(r+1 \mid t) \cdot a_{H1G}dt + W_{H2}(r \mid t) \cdot a_{H1H2}dt + \cdots + W_{A1}(r \mid t) \cdot a_{H1A1}dt + W_{H1}(r \mid t) \cdot \{1 - a_{H1G} - a_{H1H2} - \cdots - a_{H1A1})dt\}$$

$$W_{H2}(r \mid t+dt) = W_{HG}(r+1 \mid t) \cdot a_{H2HG}dt + W_{H1}(r \mid t) \cdot a_{H2H1}dt + W_{H3}(r \mid t) \cdot a_{H1H3}dt + \cdots + W_{A1}(r \mid t) \cdot a_{H2A1}dt + W_{H2}(r \mid t) \cdot \{1 - a_{H2HG} - a_{H2H1} - a_{H2H3} - \cdots - a_{H2A1})dt\}$$

… … …

$$W_{AG}(r \mid t+dt) = W_{H5}(r \mid t)$$

Boundary conditions (t = 0):

$W_{H_1}(r|0) = W_{H_2}(r|0) = \ldots = W_{A_1}(r|0)$ = 1 : $r > 0$

= 0.5 : $r = 0$

= 0 : $r < 0$

2. Markov Process Model of a Football Match

Calculation of probability of winning

$Wi(r|t)$: Probability of home team winning from a position of leading by r goals with time t remaining, starting from state i (i = H_G, H_1,H_2,…,A_G):

$$\frac{d}{dt}\begin{pmatrix} W_{H1}(r|t) \\ W_{H2}(r|t) \\ W_{H3}(r|t) \\ \\ W_{A1}(r|t) \end{pmatrix} = \begin{pmatrix} -a_{H1HG}-a_{H1H2}-[\text{redacted}] \\ a_{H2H1} \quad -a_{H2HG}-a_{H1H2}-\cdots-a_{H1A1} \quad a_{H2H3} \quad \cdots \quad a_{H2A1} \\ a_{H3H1} \quad a_{H3H2} \quad -a_{H3HG}-a_{H3H1}-\cdots-a_{H1A1} \quad \cdots \quad a_{H3A1} \\ [\text{redacted}] \\ a_{A1H1} \quad a_{A1H1} \quad a_{A1H1} \quad \cdots \quad -a_{A1AG}-a_{A1H1}-\cdots-a_{A1A2} \end{pmatrix} \begin{pmatrix} W_{H2}(r|t) \\ W_{H3}(r|t) \\ \\ W_{A1}(r|t) \end{pmatrix}$$

$$+\begin{pmatrix} \cdots & 0 & \cdots & a_{H1HG} & \cdots \\ \cdots & 0 & \cdots & a_{H2HG} & \cdots \\ \cdots & 0 & \cdots & a_{H3HG} & \cdots \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \cdots & a_{A1HG} & \cdots & 0 & \cdots \end{pmatrix} \begin{pmatrix} \vdots \\ W_{H5}(r-1|t) \\ \vdots \\ W_{A5}(r+1|t) \\ \vdots \end{pmatrix}$$

2. Markov Process Model of a Football Match

Calculation for maximizing the probability of winning

$Wi(r|t)$: Probability of home team winning from a position of leading by r goals with time t remaining, starting from state i (i = H_G, H_1,H_2,…,A_G):

$$a_{ii} = -\sum_{j \neq i} a_{ij}$$

$$W_i(r \mid t+dt) = W_{HG}(r+1 \mid t) \cdot a_{iHG}dt + W_{H1}(r \mid t) \cdot a_{iH1}dt + W_{H3}(r \mid t) \cdot a_{iH3}dt + \cdots$$
$$+ W_{A1}(r \mid t) \cdot a_{iA1}dt + W_i(r \mid t) \cdot \{1 - (a_{iHG} + a_{iH1} + a_{iH3} + \cdots + a_{iA1})dt\} + W_i(r-1 \mid t) \cdot a_{iAG}dt$$

$$= W_{HG}(r+1 \mid t) \cdot a_{iHG}dt + W_i(r \mid t) + \sum_j W_j(r \mid t) a_{ij}dt + W_{AG}(r-1 \mid t) \cdot a_{iAG}dt$$

$$W_i(r \mid t+dt) = \max \begin{cases} W_{HG}(r+1 \mid t) \cdot a_{iHG}dt + W_i(r \mid t) + \sum_j W_j(r \mid t) a_{ij}dt + W_{AG}(r-1 \mid t) \cdot a_{iAG}dt \\ W_{HG}(r+1 \mid t) \cdot a'_{iHG}dt + W_i(r \mid t) + \sum_j W_j(r \mid t) a'_{ij}dt + W_{AG}(r-1 \mid t) \cdot a'_{iAG}dt & :\text{Tactic 0} \\ W_{HG}(r+1 \mid t) \cdot a''_{iHG}dt + W_i(r \mid t) + \sum_j W_j(r \mid t) a''_{ij}dt + W_{AG}(r-1 \mid t) \cdot a''_{iAG}dt & :\text{Tactic 1} \\ \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots & :\text{Tactic 2} \end{cases}$$

3. Estimation of Transition Rates

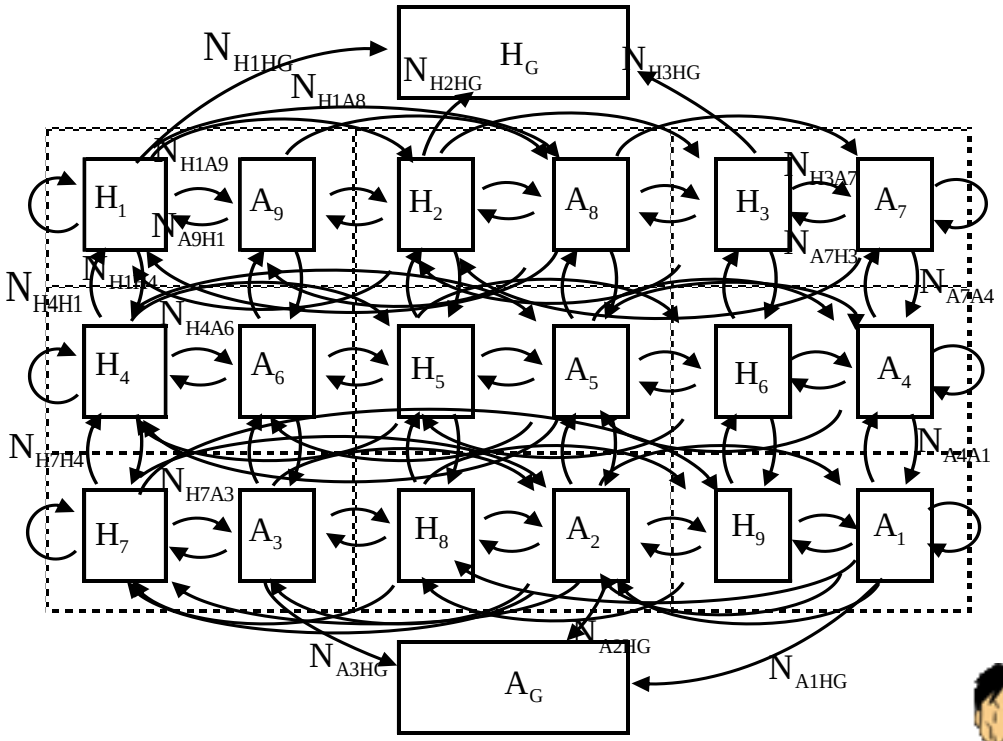
3.1 Data

To estimate the transition rates, we obtain the total numbers of transitions and the time spent in each state using annual data from J League Division 1 :

$$a_{iH_G} = N_{iH_G} / T_i \quad (i=H_1,H_2,\ldots,H_6)$$

$$a_{ij} = N_{ij} / T_i \quad (i,j=H_1,H_2,\ldots,A_1)$$

$$a_{iA_G} = N_{iA_G} / T_i \quad (i=A_1,A_2,\ldots,A_6)$$



Rates

3.1 Data

Operating revenue : 85% up to 77M€ last year

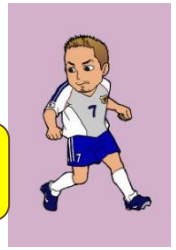


Table. Final J1 League table of the 2015 season

	Team				Goals	Goals	Away			Goals	Goals against	League Points
1	S.Hiroshim									38	17	74
2	R.Urawa			1	33	14	8	6	3	36	26	72
3	G.Osaka			1	28							
4	FCTokyo			5	25							
5	A.Kashima	34	8	3	6	29						
6	F.Kawasaki	34	10	3	4	36						
7	FM.Yokohama	34										
8	B.Shounan	34					7	4	6	18	24	48
9	G.Nagoya	34					4	3	10	16	30	46
10	R.Kashiwa	34					7	2	8	24	23	45
11	S.Tosu	34					5	5	7	22	32	40
12	V.Kobe	34					5	5	7	20	25	38
13	V.Kofu	34					7	2	8	17	23	37
14	V.Sendai	34					4	6	7	14	18	35
15	A.Niigata	34					5	4	8	24	32	34
16	Matsumoto	34	5	2	10	20	26	2	5	10	10	28	28
17	S.Shimizu	34	2	5	10	23	40	3	5	9	14	25	25
18	FM.Yamagata									8	10	28	24

Iniesta Salary: 25M€/year

Podolski Salary: 5M€/year

David Villa Salary:2.5M€/year

18 teams : 18×17＝306 games

3. Estimation of Transition Rates

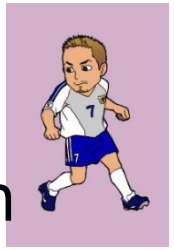
3.1 Data (provided by Data Stadium Ltd.)

V.Sendai vs. M.Yamagata

Game ID	No	Team	Player	Event	Offence No	Ball X	Ball Y	Time	Time(ms)
2015030701	1			First half Start	0	0	0	140752	900
2015030701	2	M.Yamagata	M. Yamazaki	Kick Off	1	0	0	140752	900
2015030701	3	M.Yamagata	M. Miyasaka	Trap	1	−1	−0.5	140753	200
2015030701	4	M.Yamagata	M. Miyasaka	Away Pass	1	1.5	−0.5	140753	800
2015030701	5	M.Yamagata	Arseu	Away Pass	1	35.5	−0.5	140755	467
2015030701	6	V.Sendai	J.Kamata	Home Pass	1	−86.5	55.5	140758	500
2015030701	7	M.Yamagata	Kim Bomyon	Away Pass	1	−43.5	70.5	140800	433
2015030701	8	V.Sendai	Y.Ryou	Home Pass	1	−56	21.5	140802	033
2015030701	9	M.Yamagata	K.Watanabe	Away Pass	1	71	79	140807	200
2015030701	10	M.Yamagata	Kim	Away Pass	1	59.5	95	140809	033
2015030701	11	V.Sendai	J.Kamata	Tackle	1	−17.5	62	140812	500
2015030701	12	M.Yamagata	Kim Bomyon	Away Pass	1	4.5	74	140813	800
2015030701	13	V.Sendai	Y.Ryou	Home Pass	1	−8.5	48.5	140814	800
2015030701	14	M.Yamagata	T.Ishikawa	Away Pass	1	46	66	140816	700
2015030701	15	V.Sendai	H.Okuno	Trap	2	28.5	56.5	140818	567
2015030701	16	V.Sendai	H.Okuno	Home Pass	2	29	59.5	140819	667
2015030701	17	V.Sendai	S.Mogi	Trap	2	29.5	92.5	140820	533
2015030701	18	M.Yamagata	S.Ito	Foul	2	35	79.5	140822	333
2015030701	19	V.Sendai	S.Mogi	get Foul	2	35	79.5	140822	333
2015030701	20	V.Sendai	Y.Ryou	Direct FK	3	44	79	140847	967
2015030701	21	V.Sendai	N.Ishikawa	Home Pass	3	118.5	−33.5	140850	867
2015030701	22	M.Yamagata	M. Miyasaka	Away Pass	3	96	−13	140852	934
2015030701	23	V.Sendai	H.Okuno	Shoot	3	79.5	−3	140853	967
2015030701	24	V.Sendai	H.Okuno	Ball Out	3	159.5	9.5	140855	467
2015030701	25	M.Yamagata	N.Yamagishi	GK	4	143.5	16	140918	333
2015030701	26	M.Yamagata	Diego	Away Pass	4	−19	68.5	140921	700
2015030701	27	V.Sendai	H.Watabe	Home Pass	4	−48.5	46.5	140923	533
2015030701	28	M.Yamagata	K.Watanabe	Away Pass	4	40	22.5	140925	700
2015030701	29	V.Sendai	Lopes	Trap	5	53	34.5	140927	867
2015030701	30	V.Sendai	Lopes	Home Pass	5	65	36.5	140928	900
2015030701	31	M.Yamagata	K.Tomima	Away Pass	5	101	7.5	140930	533
2015030701	32	V.Sendai	S.Mogi	Trap	5	67.5	53.5	140932	700
2015030701	33	V.Sendai	S.Mogi	Home Pass	5	52	48.5	140934	233
2015030701	34	V.Sendai	N.Sugai	Trap	5	41.5	76.5	140935	600
2015030701	35	V.Sendai	N.Sugai	Home Pass	5	52.5	84.5	140937	133
2015030701	36	V.Sendai	Lopes	Dribble	5	84.5	98	140938	066
2015030701	37	M.Yamagata	T.Ishikawa	Foul	5	76	97	140939	633
2015030701	38	V.Sendai	Lopes	get Foul	5	76	97	140939	633
2015030701	39	V.Sendai	Y.Ryou	Direct FK	6	72.5	90.5	141020	300
2015030701	40	M.Yamagata	Arseu	Trap	7	131.5	7	141022	100
2015030701	41	M.Yamagata	Arseu	Away Pass	7	136	9	141023	400
2015030701	42	V.Sendai	H.Watabe	Foul	7	133.5	11	141023	834
2015030701	43	M.Yamagata	Arseu	get Foul	7	133.5	11	141023	834
2015030701	44	M.Yamagata	N.Yamagishi	Direct FK	8	123	7.5	141049	834
2015030701	45	M.Yamagata	Arseu	Away Pass	8	−23	72.5	141053	000
...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...

3. Estimation of Transition Rates

3.1. Data



Histogram of consecutive possession time in a match

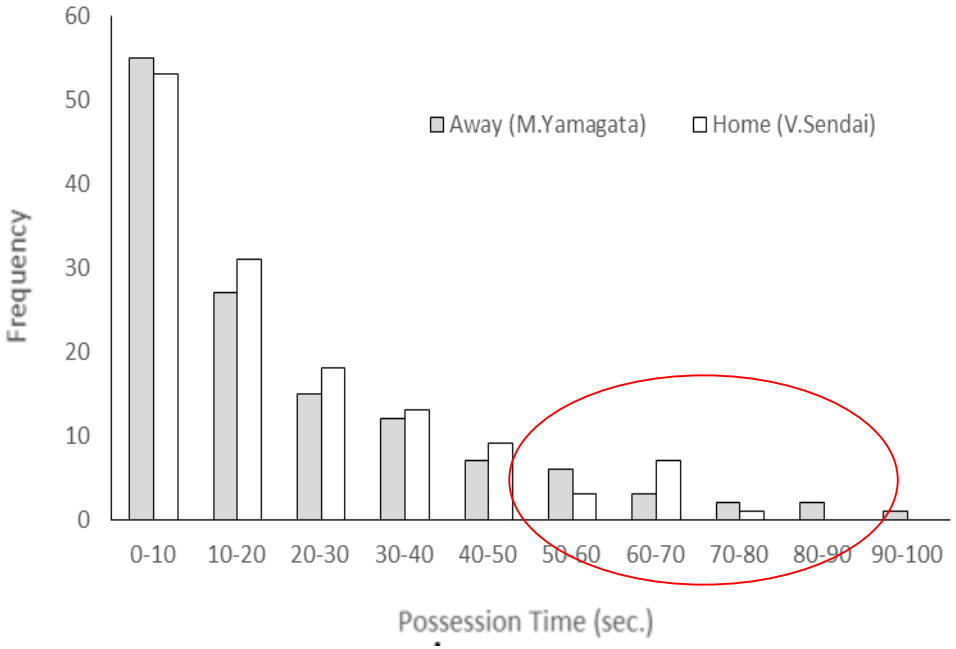


Figure. Histogram of consecutive possession time in a game (V.Sendai vs.M.Yamagata)

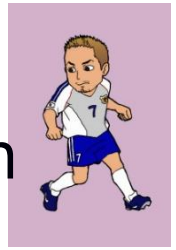
We do not include the time of

Ball-out, Foul, Penalty, Offside, Substitution and Goal.

3. Estimation of Transition Rates

3.1. Data

Histogram of consecutive possession time in a match



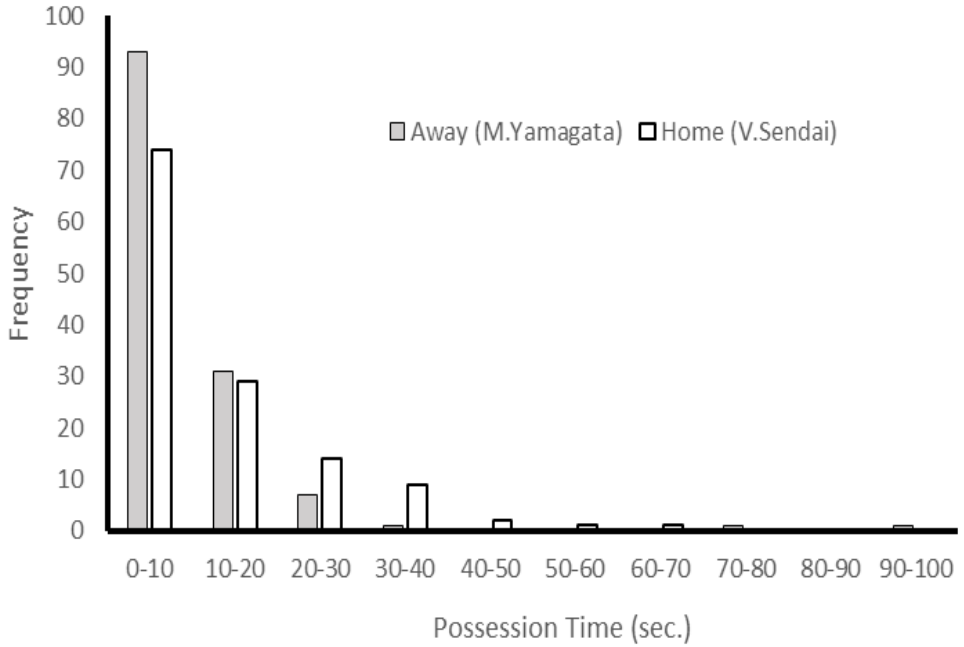


Figure. Histogram of consecutive possession time in a game (V.Sendai vs.M.Yamagata)

We do not include the time of

Ball-out, Foul, Penalty, Offside, Substitution and Goal.

3. Estimation of Transition Rates

3.1. Data

Table 2: Observed number of goals, transitions, and time for each game

No.	Home	Away	Goal						Transition					...						Time (min,)					...					
			N_{H1G}	N_{H2G}	N_{H3G}	N_{A9G}	N_{A8G}	N_{A7G}	N_{H1H2}	N_{H1A2}	N_{H3H2}	N_{H5H2}	N_{H5A5}	...	N_{A9A8}	N_{A8H8}	N_{A7A8}	N_{A5A8}	N_{A5H5}	T_{H1}	T_{H2}	T_{H3}	T_{H4}	T_{H5}	...	T_{A5}	T_{A4}	T_{A3}	T_{A2}	T_{A1}
1	V.Sendai	M.Yamagata	0	2	0	0	0	0	13	2	10	3	2		12	11	22	6	6	1.4	1.3	2.1	3.2	2.9		3.1	3.7	2.5	3.0	2.0
2	M.Yamagata	V.Sendai	0	1	0	0	1	0	13	2	6	5	3		12	14	10	5	6	3.0	2.1	1.8	4.3	2.1		2.1	3.1	1.3	3.7	2.0
3	S.Hiroshima	V.Sendai	0	2	0	0	0	0	12	4	17	3	3		7	15	11	8	3	2.9	1.9	2.8	3.4	3.4		6.7	6.4	1.1	3.5	1.2
4	V.Sendai	S.Hiroshima	0	3	0	0	3	1	22	2	19	8	2		7	8	9	5	4	4.2	3.5	3.5	6.6	6.9		3.3	2.8	3.3	4.0	2.1
5	S.Hiroshima	M.Yamagata	0	5	0	0	1	0	13	4	14	9	6		17	18	16	9	4	2.3	2.2	1.4	4.3	3.3		4.8	3.7	1.4	2.8	0.8
6	M.Yamagata	S.Hiroshima	0	1	0	0	2	1	19	4	11	10	2		9	13	14	3	5	2.5	2.0	2.6	4.1	5.9		4.1	4.8	3.3	6.7	2.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
305	A.Niigata	V.Kofu	0	0	0	0	2	0	16	5	11	12	3		10	32	6	6	2	3.3	4.1	1.7	6.4	6.4		3.6	4.6	2.0	4.7	1.9
306	S.Shimizu	V.Kofu	0	0	0	1	1	0	27	8	22	12	3		8	13	3	2	5	3.5	5.3	2.6	7.3	5.3		1.9	2.7	2.4	4.2	2.1
Total			14	404	12	6	364	18												830.3	790.4	751.9	1426.1	1243.4		1220.5	1304.7	574.5	1110.7	564.5

3. Estimation of Transition Rates

3.1. Data

Table 2: Observed number of goals, transitions, and time for each game

No.	Home	Away	Goal						Transition					...						Time (min.)					...					
			N_{H1G}	N_{H2G}	N_{H3G}	N_{A1G}	N_{A2G}	N_{A3G}	N_{H1H2}	N_{H1A8}	N_{H3H2}	N_{H5H2}	N_{H5A5}	...	N_{A1A2}	N_{A2H8}	N_{A3A2}	N_{A5A2}	N_{A5H5}	T_{H1}	T_{H2}	T_{H3}	T_{H4}	T_{H5}	...	T_{A5}	T_{A6}	T_{A7}	T_{A8}	T_{A9}
1	V.Sendai	M.Yamagata	0	2	0	0	0	0	13	2	10	3	2		12	11	22	6	6	1.4	1.3	2.1	3.2	2.9		3.1	3.7	2.5	3.0	2.0
2	M.Yamagata	V.Sendai	0	1	0	0	1	0	13	2	6	5	3		12	14	10	5	6	3.0	2.1	1.8	4.3	2.1		2.1	3.1	1.3	3.7	2.0
3	S.Hiroshima	V.Sendai	0	2	0	0	0	0	12	4	17	3	3		7	15	11	8	3	2.9	1.9	2.8	3.4	3.4		6.7	6.4	1.1	3.5	1.2
4	V.Sendai	S.Hiroshima	0	3	0	0	3	1	22	2	19	8	2		7	8	9	5	4	4.2	3.5	3.5	6.6	6.9		3.3	2.8	3.3	4.0	2.1
5	S.Hiroshima	M.Yamagata	0	5	0	0	1	0	13	4	14	9	6		17	18	16	9	4	2.3	2.2	1.4	4.3	3.3		4.8	3.7	1.4	2.8	0.8
6	M.Yamagata	S.Hiroshima	0	1	0	0	2	1	19	4	11	10	2		9	13	14	3	5	2.5	2.0	2.6	4.1	5.9		4.1	4.8	3.3	6.7	2.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
305	A.Niigata	V.Kofu	0	0	0	0	2	0	16	5	11	12	3		10	32	6	6	2	3.3	4.1	1.7	6.4	6.4		3.6	4.6	2.0	4.7	1.9
306	S.Shimizu	V.Kofu	0	0	0	1	1	0	27	8	22	12	3		8	13	3	2	5	3.5	5.3	2.6	7.3	5.3		1.9	2.7	2.4	4.2	2.1
	Total		14	404	12	6	364	18	4612	1418	4366	2026	1451		3833	4814	3969	1953	1548	830.3	790.4	751.9	1426.1	1243.4		1220.5	1304.7	574.5	1110.7	564.5
	Average (par game)		0.05	1.32	0.04	0.02	1.19	0.06	15.1	4.6	14.3	6.6	4.7		12.5	15.7	13.0	6.4	5.1	2.7	2.6	2.5	4.7	4.1		4.0	4.3	1.9	3.6	1.8

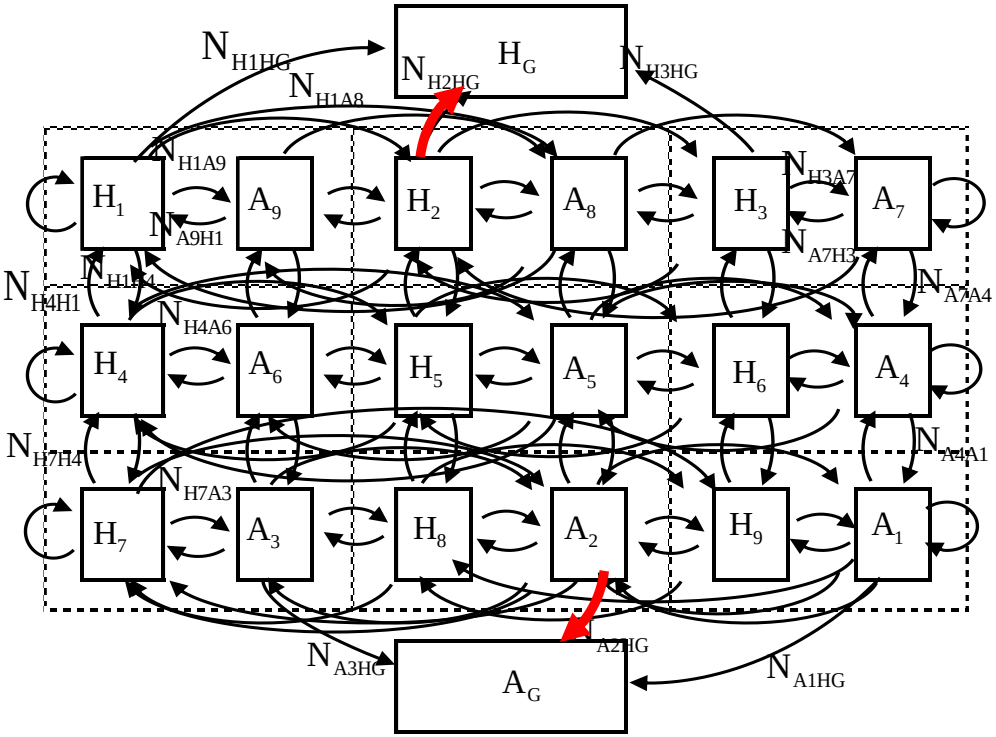
Net Time:55.17min/game

3. Estimation of Transition Rates

3.2. Goal-scoring rates

Average (per game) (Mean ± SD)

↗	H_G	A_G	Time
H_1	0.05 ± 0.22	-	2.71 ± 1.04
H_2	1.32 ± 1.31	-	2.58 ± 0.99
H_3	0.04 ± 0.19	-	2.46 ± 0.85
H_4	0.00 ± 0.06	-	4.66 ± 1.59
H_5	0.00 ± 0.00	-	4.06 ± 1.61
H_6	0.00 ± 0.06	-	4.41 ± 1.47
A_6	-	0.00 ± 0.00	4.26 ± 1.37
A_5	-	0.00 ± 0.00	3.99 ± 1.91
A_4	-	0.00 ± 0.00	4.47 ± 1.43
A_3	-	0.06 ± 0.26	2.35 ± 0.90
A_2	-	1.19 ± 1.08	2.38 ± 0.92
A_1	-	0.02 ± 0.14	2.31 ± 0.89



$$N_{H_2H_G} / T_{H2} = 1.32 / 2.58 = 0.511 \text{ [goals / min]}$$

$$N_{A_2A_G} / T_{A2} = 1.19 / 2.38 = 0.500 \text{ [goals / min]}$$

3. Estimation of Transition Rates 3.3 Transition rate on possession

	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	Time
H_1		15.1 ± 6.2	1.3 ± 1.2	8.4 ± 4.1	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.4	0.0 ± 0.2	0.0 ± 0.1	8.5 ± 3.6	4.6 ± 2.3	0.2 ± 0.4	0.6 ± 0.8	0.1 ± 0.2	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	2.71 ± 1.04
H_2	8.6 ± 4.5		8.6 ± 4.4	1.6 ± 1.5	3.9 ± 2.5	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.3	0.1 ± 0.2	0.8 ± 1.0	17.6 ± 5.2	0.7 ± 0.8	0.3 ± 0.5	1.5 ± 1.3	0.1 ± 0.3	0.0 ± 0.2	0.3 ± 0.5	0.0 ± 0.1	2.58 ± 0.99
H_3	1.3 ± 1.2	14.3 ± 5.7		0.2 ± 0.5	1.3 ± 1.2	7.7 ± 4.3	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.1 ± 0.4	5.1 ± 2.6	7.9 ± 3.1	0.1 ± 0.3	0.1 ± 0.2	0.4 ± 0.6	0.0 ± 0.0	0.0 ± 0.1	0.0 ± 0.0	2.46 ± 0.85
H_4	19.1 ± 6.4	2.2 ± 2.1	1.1 ± 1.1		18.0 ± 9.9	1.8 ± 1.8	5.6 ± 3.1	3.0 ± 2.0	0.2 ± 0.4	2.9 ± 1.9	1.3 ± 1.1	0.2 ± 0.4	8.6 ± 3.6	0.8 ± 0.9	0.1 ± 0.4	0.3 ± 0.6	0.0 ± 0.1	0.0 ± 0.0	4.66 ± 1.59
H_5	5.1 ± 2.7											0.6 ± 0.8	0.7 ± 0.9	4.7 ± 2.4	0.6 ± 0.7	0.0 ± 0.1	0.0 ± 0.2	0.0 ± 0.1	4.06 ± 1.61
H_6	1.1 ± 1.3											3.0 ± 1.9	0.1 ± 0.3	1.0 ± 1.0	8.3 ± 4.0	0.0 ± 0.2	0.0 ± 0.2	0.3 ± 0.6	4.41 ± 1.47
H_7	0.9 ± 1.1											0.0 ± 0.2	1.9 ± 1.4	0.5 ± 0.7	0.0 ± 0.2	2.5 ± 1.9	0.1 ± 0.3	0.0 ± 0.1	1.86 ± 0.60
H_8	1.1 ± 1.3	1.0 ± 1.3	1.0 ± 1.3	7.7 ± 3.3	11.9 ± 4.9	8.0 ± 3.6	8.7 ± 4.8		8.6 ± 4.6	0.4 ± 0.7	0.6 ± 0.9	0.4 ± 0.6	1.1 ± 1.1	1.7 ± 1.4	1.1 ± 1.1	0.2 ± 0.5	0.8 ± 0.9	0.2 ± 0.4	3.47 ± 0.87
H_9	0.1 ± 0.3	0.4 ± 0.7	0.9 ± 1.2	0.3 ± 0.5	2.5 ± 1.8	12.0 ± 5.0	0.6 ± 0.9	7.4 ± 4.7		0.0 ± 0.2	0.3 ± 0.6	0.5 ± 0.7	0.1 ± 0.2	0.5 ± 0.7	1.9 ± 1.5	0.0 ± 0.1	0.1 ± 0.3	2.5 ± 1.8	1.85 ± 0.63
A_9	2.7 ± 2.0	0.1 ± 0.3	0.0 ± 0.1	2.2 ± 1.7	0.6 ± 0.9	0.1 ± 0.2	0.6 ± 0.8	0.3 ± 0.5	0.1 ± 0.2		6.8 ± 4.2	0.5 ± 0.8	11.6 ± 4.4	2.2 ± 1.5	0.3 ± 0.5	1.1 ± 1.2	0.4 ± 0.7	0.1 ± 0.3	1.84 ± 0.60
A_8	0.2 ± 0.5	1.1 ± 1.2	0.3 ± 0.5	1.2 ± 1.3	1.8 ± 1.3	1.3 ± 1.3	0.5 ± 0.7	0.6 ± 0.9	0.4 ± 0.7	8.6 ± 4.1		9.3 ± 4.8	8.1 ± 3.6	11.7 ± 4.9	8.2 ± 3.8	1.0 ± 1.3	1.0 ± 1.3	1.1 ± 1.4	3.63 ± 0.91
A_7	0.0 ± 0.0	0.1 ± 0.4	2.8 ± 1.9	0.1 ± 0.3	0.5 ± 0.8	2.1 ± 1.5	0.0 ± 0.1	0.2 ± 0.4	0.4 ± 0.7	0.5 ± 0.8	7.1 ± 4.1		0.3 ± 0.6	2.4 ± 1.6	12.5 ± 4.7	0.0 ± 0.2	0.2 ± 0.4	0.7 ± 0.9	1.88 ± 0.57
A_6	0.3 ± 0.6	0.0 ± 0.1	0.1 ± 0.3	8.9 ± 3.6	0.9 ± 1.1	0.1 ± 0.3	3.1 ± 1.9	1.3 ± 1.2	0.2 ± 0.5	5.4 ± 3.2	2.7 ± 2.1	0.1 ± 0.4		15.8 ± 9.0	1.5 ± 1.5	17.4 ± 6.1	3.4 ± 2.1	1.0 ± 1.2	4.26 ± 1.37
A_5	0.0 ± 0.1	0.1 ± 0.3	0.0 ± 0.2	0.7 ± 0.9	5.1 ± 2.2	0.7 ± 0.9	0.6 ± 0.8	1.5 ± 1.3	0.6 ± 0.8	0.9 ± 0.9	4.1 ± 2.6	1.0 ± 1.1	18.3 ± 9.3		18.3 ± 9.5	4.2 ± 2.6	6.4 ± 3.8	4.3 ± 2.5	3.99 ± 1.91
A_4	0.0 ± 0.2	0.0 ± 0.1	0.3 ± 0.6	0.2 ± 0.4	0.9 ± 1.0	8.7 ± 3.6	0.2 ± 0.4	1.1 ± 1.1	3.0 ± 1.9	0.1 ± 0.3	2.6 ± 1.9	5.7 ± 3.0	1.5 ± 1.5	16.8 ± 9.3		1.0 ± 1.1	3.0 ± 2.0	17.0 ± 6.3	4.47 ± 1.43
A_3	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.1	0.5 ± 0.7	0.1 ± 0.2	0.0 ± 0.2	7.8 ± 3.2	4.7 ± 2.2	0.2 ± 0.4	0.1 ± 0.3	0.0 ± 0.1	0.0 ± 0.1	7.6 ± 3.9	1.3 ± 1.3	0.1 ± 0.4		13.0 ± 5.5	1.3 ± 1.3	2.35 ± 0.90
A_2	0.0 ± 0.2	0.4 ± 0.6	0.0 ± 0.2	0.2 ± 0.5	1.3 ± 1.1	0.1 ± 0.3	0.6 ± 0.8	15.7 ± 4.8	0.9 ± 1.0	0.1 ± 0.3	0.1 ± 0.4	0.1 ± 0.2	1.5 ± 1.3	3.8 ± 2.5	1.3 ± 1.2	7.8 ± 3.9		7.4 ± 3.7	2.38 ± 0.92
A_1	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.2	0.5 ± 0.7	0.1 ± 0.3	4.4 ± 2.2	8.0 ± 3.4	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.2 ± 0.4	1.2 ± 1.1	7.5 ± 3.8	1.1 ± 1.0	12.5 ± 5.0		2.31 ± 0.89

$$N_{H_4H_1} / T_{H4} = 19.1 / 4.66 = 4.09 \text{ [times / min]]}$$

3. Estimation of Transition Rates　3.3 Transition rate on possession

	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1
H_1	-	5.55 ± 2.28	0.48 ± 0.42	3.09 ± 1.53	0.54 ± 0.51	0.04 ± 0.13	0.05 ± 0.15	0.01 ± 0.07	0.01 ± 0.05	3.12 ± 1.33	1.71 ± 0.85	0.06 ± 0.15	0.21 ± 0.28	0.02 ± 0.09	0.01 ± 0.06	0.00 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
H_2	3.33 ± 1.76	-	3.34 1.71	0.62 0.57	1.50 0.95	0.57 0.53	0.05 0.14	0.04 0.13	0.02 0.09	0.32 0.40	6.81 2.02	0.25 0.30	0.11 0.20	0.59 0.50	0.03 0.11	0.01 0.07	0.12 0.20	0.01 0.05
H_3	0.52 ± 0.48	5.81 ± 2.33	-	0.09 ± 0.20	0.51 ± 0.48	3.14 ± 1.74	0.00 ± 0.03	0.02 ± 0.09	0.03 ± 0.10	0.05 ± 0.14	2.09 ± 1.06	3.23 ± 1.28	0.04 ± 0.13	0.02 ± 0.10	0.16 ± 0.26	0.00 ± 0.00	0.00 ± 0.02	0.00 ± 0.00
H_4	4.09 ± 1.38	0.70 ± 0.45	0.23 ± 0.23	-	3.86 ± 2.12	0.38 ± 0.38	1.21 ± 0.67	0.65 ± 0.43	0.03 ± 0.08	0.62 ± 0.40	0.27 ± 0.24	0.04 ± 0.09	1.84 ± 0.77	0.18 ± 0.20	0.03 ± 0.08	0.07 ± 0.13	0.00 ± 0.03	0.01 ± 0.04
H_5	1.24 ± 0.66										± 0.32	0.15 ± 0.20	0.18 ± 0.22	1.17 ± 0.58	0.14 ± 0.17	0.00 ± 0.03	0.01 ± 0.06	0.01 ± 0.04
H_6	0.25 ± 0.29										± 0.28	0.68 ± 0.44	0.03 ± 0.08	0.22 ± 0.22	1.88 ± 0.91	0.01 ± 0.04	0.01 ± 0.04	0.07 ± 0.13
H_7	0.50 ± 0.57										± 0.19	0.02 ± 0.10	1.05 ± 0.74	0.28 ± 0.38	0.02 ± 0.09	1.33 ± 1.00	0.05 ± 0.18	0.00 ± 0.03
H_8	0.32 ± 0.36	0.28 ± 0.36	0.30 ± 0.38	2.22 ± 0.95	3.41 ± 1.41	2.30 ± 1.03	2.50 ± 1.38	-	2.48 ± 1.33	0.12 ± 0.21	0.18 ± 0.26	0.11 ± 0.18	0.31 ± 0.33	0.48 ± 0.40	0.33 ± 0.32	0.07 ± 0.14	0.23 ± 0.25	0.06 ± 0.12
H_9	0.05 ± 0.16	0.22 ± 0.38	0.50 ± 0.65	0.14 ± 0.30	1.33 ± 0.96	6.50 ± 2.69	0.33 ± 0.51	3.98 ± 2.55	-	0.01 ± 0.09	0.16 ± 0.30	0.26 ± 0.37	0.03 ± 0.12	0.25 ± 0.37	1.02 ± 0.80	0.01 ± 0.05	0.05 ± 0.16	1.35 ± 0.96
A_9	1.47 ± 1.06	0.06 ± 0.17	0.01 ± 0.07	1.20 ± 0.92	0.33 ± 0.47	0.03 ± 0.13	0.32 ± 0.44	0.14 ± 0.29	0.03 ± 0.13	-	3.69 ± 2.28	0.27 ± 0.43	6.30 ± 2.40	1.20 ± 0.82	0.14 ± 0.28	0.58 ± 0.65	0.22 ± 0.39	0.03 ± 0.15
A_8	0.07 ± 0.14	0.30 ± 0.33	0.07 ± 0.15	0.34 ± 0.36	0.50 ± 0.35	0.35 ± 0.35	0.14 ± 0.20	0.15 ± 0.24	0.10 ± 0.19	2.36 ± 1.14	-	2.56 ± 1.32	2.22 ± 1.00	3.22 ± 1.34	2.26 ± 1.04	0.27 ± 0.36	0.27 ± 0.36	0.30 ± 0.39
A_7	0.00 ± 0.00	0.06 ± 0.20	1.49 ± 1.00	0.04 ± 0.14	0.29 ± 0.41	1.13 ± 0.82	0.01 ± 0.07	0.10 ± 0.23	0.24 ± 0.37	0.26 ± 0.44	3.81 ± 2.21	-	0.18 ± 0.34	1.30 ± 0.87	6.64 ± 2.48	0.03 ± 0.12	0.10 ± 0.22	0.38 ± 0.48
A_6	0.08 ± 0.13	0.00 ± 0.03	0.02 ± 0.06	2.10 ± 0.85	0.22 ± 0.25	0.03 ± 0.07	0.72 ± 0.44	0.30 ± 0.27	0.05 ± 0.11	1.26 ± 0.75	0.64 ± 0.49	0.03 ± 0.09	-	3.70 ± 2.10	0.36 ± 0.34	4.08 ± 1.42	0.80 ± 0.50	0.23 ± 0.27
A_5	0.01 ± 0.04	0.02 ± 0.07	0.01 ± 0.05	0.17 ± 0.22	1.27 ± 0.54	0.18 ± 0.23	0.14 ± 0.20	0.39 ± 0.33	0.16 ± 0.21	0.24 ± 0.24	1.02 ± 0.66	0.26 ± 0.28	4.58 ± 2.33	-	4.59 ± 2.38	1.04 ± 0.65	1.60 ± 0.96	1.09 ± 0.63
A_4	0.01 ± 0.04	0.00 ± 0.03	0.07 ± 0.12	0.04 ± 0.09	0.19 ± 0.22	1.95 ± 0.80	0.04 ± 0.08	0.24 ± 0.25	0.67 ± 0.42	0.02 ± 0.07	0.58 ± 0.43	1.27 ± 0.67	0.34 ± 0.33	3.77 ± 2.09	-	0.23 ± 0.25	0.67 ± 0.45	3.80 ± 1.41
A_3	0.00 ± 0.02	0.00 ± 0.00	0.00 ± 0.02	0.20 ± 0.30	0.03 ± 0.11	0.01 ± 0.08	3.31 ± 1.36	2.01 ± 0.96	0.07 ± 0.16	0.03 ± 0.11	0.01 ± 0.05	0.01 ± 0.05	3.23 ± 1.66	0.56 ± 0.54	0.06 ± 0.16	-	5.52 ± 2.34	0.55 ± 0.54
A_2	0.02 ± 0.08	0.16 ± 0.27	0.01 ± 0.07	0.10 ± 0.21	0.55 ± 0.48	0.03 ± 0.11	0.25 ± 0.34	6.62 ± 2.01	0.40 ± 0.43	0.03 ± 0.12	0.06 ± 0.16	0.03 ± 0.10	0.62 ± 0.53	1.58 ± 1.03	0.53 ± 0.50	3.28 ± 1.65	-	3.09 ± 1.57
A_1	0.00 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.13	0.02 ± 0.09	0.22 ± 0.32	0.04 ± 0.14	1.90 ± 0.95	3.46 ± 1.47	0.01 ± 0.05	0.01 ± 0.08	0.05 ± 0.15	0.08 ± 0.18	0.51 ± 0.49	3.25 ± 1.65	0.49 ± 0.45	5.43 ± 2.18	-

$$N_{H_4H_1} / T_{H4} = 19.1 / 4.66 = 4.09 \text{ [times / min]}$$

4. Calculation Result

4.1 Probability of staying state i

$\pi_i(t)$: Probability of staying state *i* at a time t after the kick off (i = $H_1, H_2, \ldots, A_1$):

$$\pi_{H_1}(t+dt) = \pi_{H_2}(t)\cdot a_{H_2H_1}dt + \pi_{H_3}(t)\cdot a_{H_3H_1}dt + \cdots + \pi_{A_1}(t)\cdot a_{A_1H_1}dt + \pi_{H_1}(n\,|\,t)\cdot\left\{1-(a_{H_2H_1}+a_{H_3H_1}+\cdots+a_{A_1H_1})dt\right\}$$

$$\pi_{H_2}(t+dt) = \pi_{H_1}(t)\cdot a_{H_1H_2}dt + \pi_{H_3}(t)\cdot a_{H_3H_2}dt + \cdots + \pi_{A_1}(t)\cdot a_{A_1H_2}dt + \pi_{H_2}(n\,|\,t)\cdot\left\{1-(a_{H_1H_2}+a_{H_3H_2}+\cdots+a_{A_1H_2})dt\right\}$$

… … …

$$\pi_{A_1}(t+dt) = \pi_{H_1}(t)\cdot a_{H_1A_1}dt + \pi_{H_2}(t)\cdot a_{H_2A_1}dt + \cdots + \pi_{A_2}(t)\cdot a_{A_2A_1}dt + \pi_{A_1}(n\,|\,t)\cdot\left\{1-(a_{H_1A_1}+a_{H_2A_1}+\cdots+a_{A_2A_1})dt\right\}$$

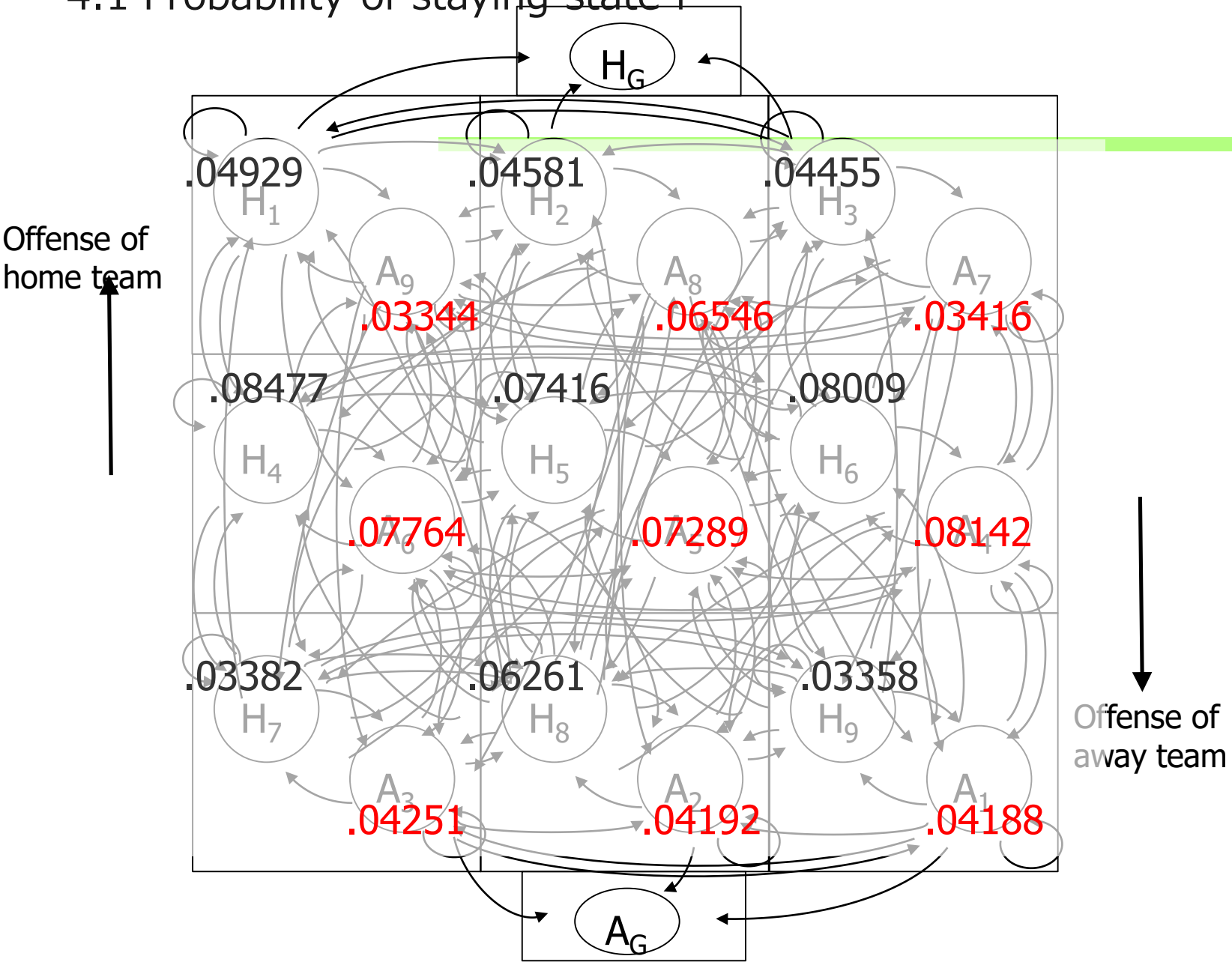
Initial condition (t = 0):

$\pi_i(0)$ =1 : i =H_5 (or A_5)

$\pi_i(0)$ = 0 : Otherwise

4. Calculation Result

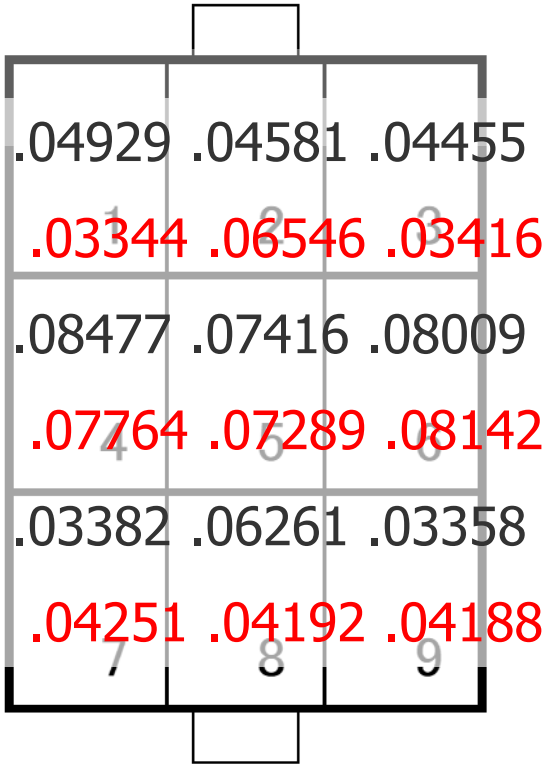
4.1 Probability of staying state i



4. Calculation Result

4.1 Probability of staying state i

Offense of home team



Net Time:55.17min/game

4. Calculation Result

4.1 Probability of staying state i

Calculation result in terms of the time spent in each state (min)

Offense of home team

Expected

2.72	2.53	2.46
1.84	3.61	1.88
4.68	4.09	4.42
4.28	4.02	4.49
1.87	3.45	1.85
2.35	2.31	2.31

Observed

2.71	2.58	2.46
1.84	3.63	1.88
4.66	4.06	4.41
4.26	3.99	4.47
1.86	3.47	1.85
2.35	2.38	2.31

Relative Error <3%

4. Calculation Result

4.2 Probability distribution of the number of goals

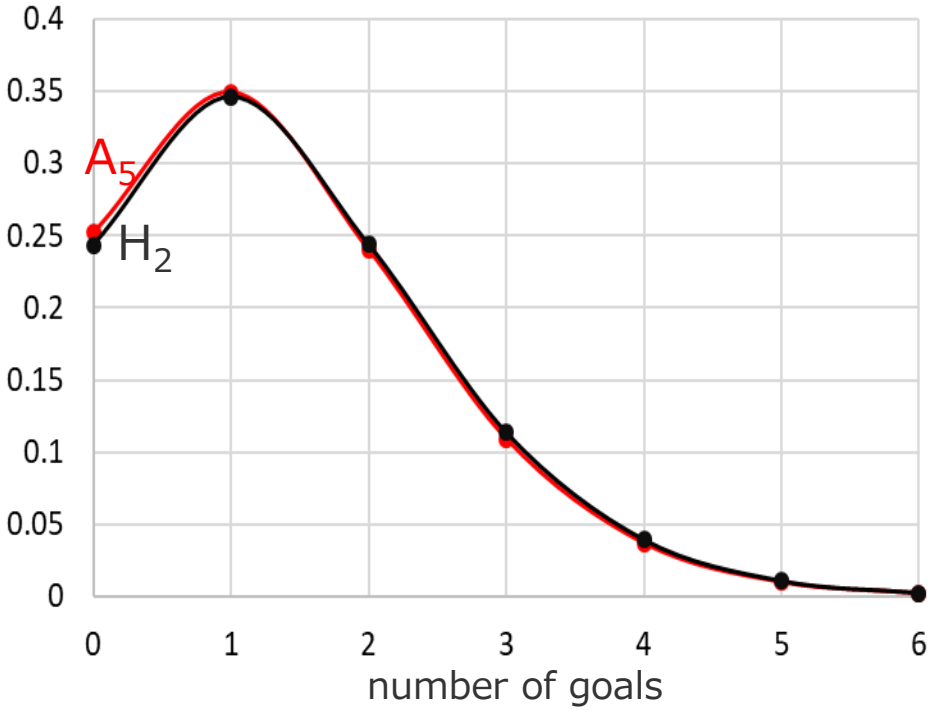
Calculation result in terms of the probability distribution of the number of goals by **home team**

Expected number of goals

Offense of home team

1.382	1.401	1.382
1.369 (1)	1.368 (2)	1.369 (3)
1.375	1.376	1.375
1.368 (4)	1.368 (5)	1.368 (6)
1.372	1.373	1.372
1.369 (7)	1.370 (8)	1.369 (9)

Probability distribution



4. Calculation Result

4.2 Probability distribution of the number of goals

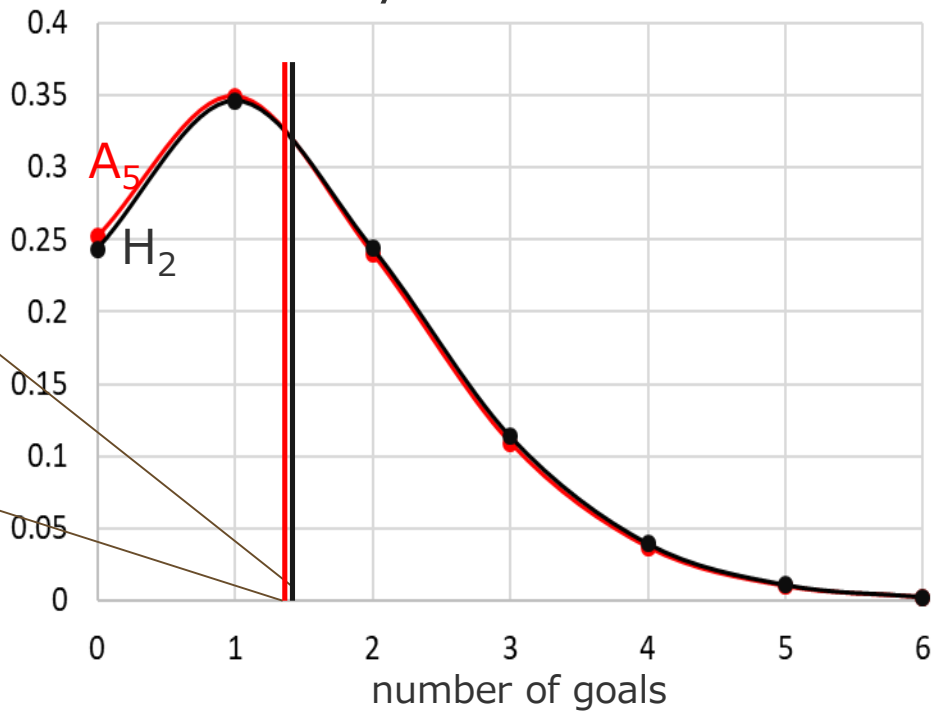
Calculation result in terms of the probability distribution of the number of goals by **home team**

Expected number of goals

Offense of home team

1.382	1.401	1.382
1.369 (1)	1.368 (2)	1.369 (3)
1.375	1.376	1.375
1.368 (4)	1.368 (5)	1.368 (6)
1.372	1.373	1.372
1.369 (7)	1.370 (8)	1.369 (9)

Probability distribution



4. Calculation Result

4.2 Probability distribution of the number of goals

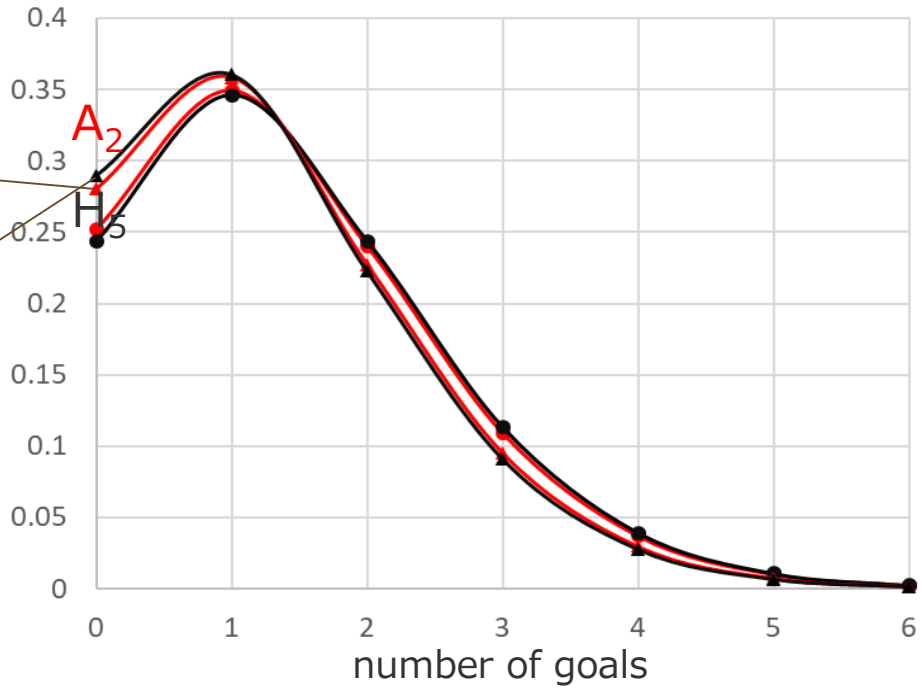
Calculation result in terms of the probability distribution of the number of goals by **away team**

Expected number of goals

Offense of away team

1.244	1.264	1.245
1.232	1.231	1.232
1.238	1.239	1.238
1.231	1.231	1.231
1.235	1.236	1.235
1.232	1.233	1.232

Probability distribution



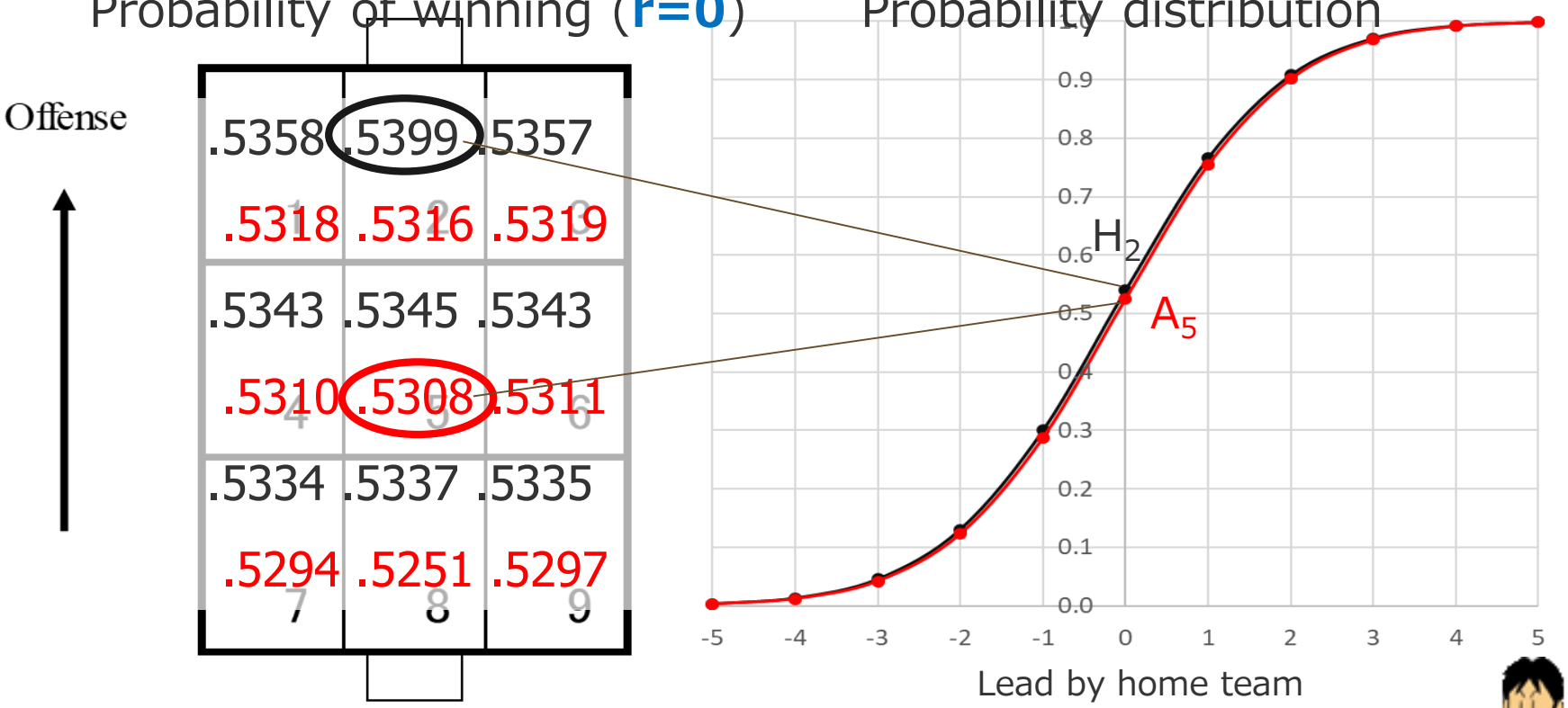
4. Calculation Result

4.3 Probability of the **home team** winning the game

Calculation result in terms of the probability of the **home team** winning the game

Probability of winning (**r=0**)

Probability distribution



4. Calculation Result

4.3 Probability of the **home team** winning the game

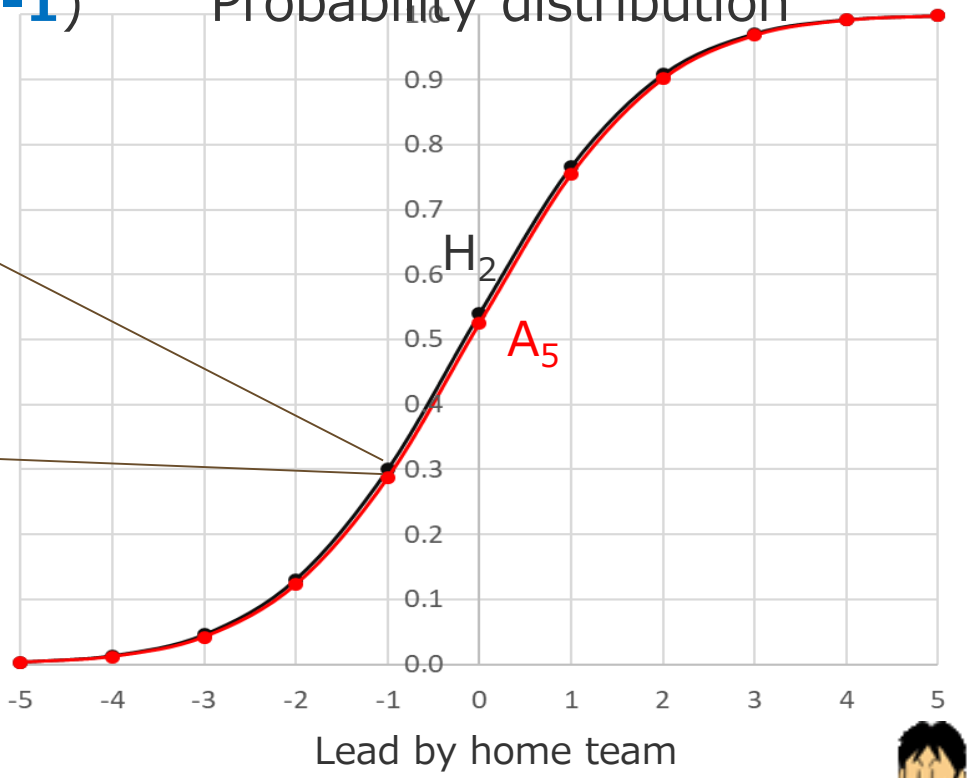
Calculation result in terms of the probability of the **home team** winning the game

Probability of winning (**r=-1**)

Offense of home team

.2957	.3001	.2957
.2919 (1)	.2917 (2)	.2919 (3)
.2941	.2943	.2941
.2913 (4)	.2911 (5)	.2913 (6)
.2933	.2935	.2933
.2902 (7)	.2873 (8)	.2904 (9)

Probability distribution



4. Calculation Result

4.3 Probability of the **home team** winning the game

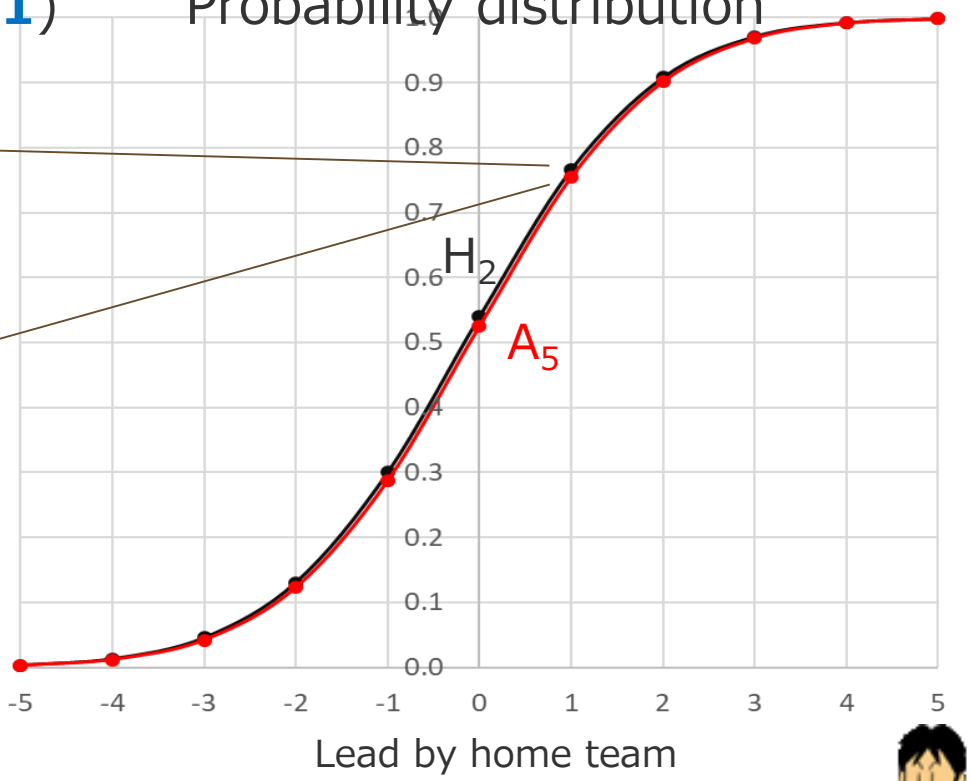
Calculation result in terms of the probability of the **home team** winning the game

Probability of winning (**r=1**)

Offense of home team

.7638	.7664	.7638
.7611	.7609	.7612
.7629	.7631	.7629
.7603	.7601	.7604
.7624	.7626	.7624
.7588	.7546	.7591

Probability distribution



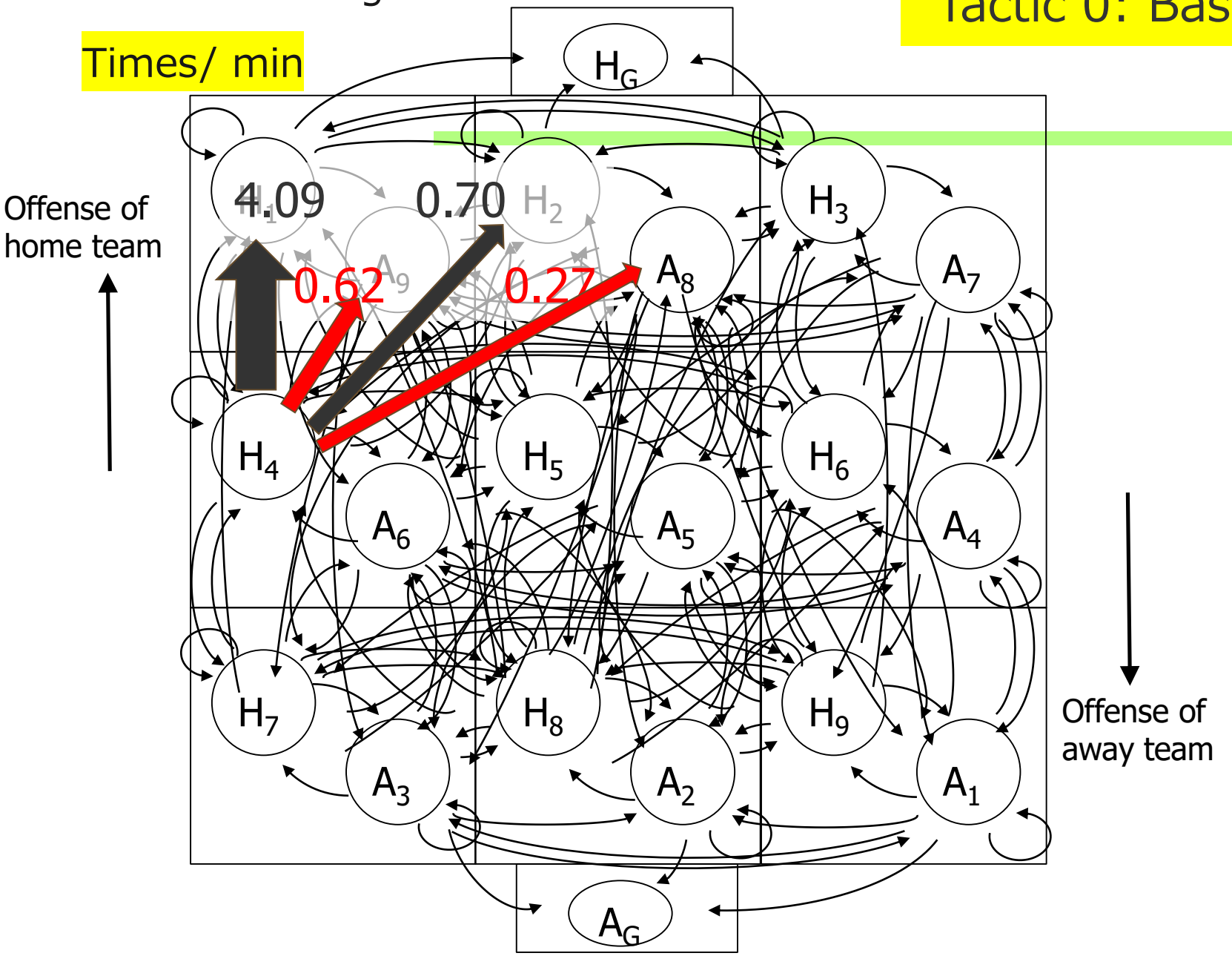
4. Calculation Result 4.4 Effect of a change of transition rates

	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1
H_1	-	5.55 ± 2.28	0.48 ± 0.42	3.09 ± 1.53	0.54 ± 0.51	0.04 ± 0.13	0.05 ± 0.15	0.01 ± 0.07	0.01 ± 0.05	3.12 ± 1.33	1.71 ± 0.85	0.06 ± 0.15	0.21 ± 0.28	0.02 ± 0.09	0.01 ± 0.06	0.00 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
H_2	3.33 ± 1.76	-	3.34 1.71	0.62 0.57	1.50 0.95	0.57 0.53	0.05 0.14	0.04 0.13	0.02 0.09	0.32 0.40	6.81 2.02	0.25 0.30	0.11 0.20	0.59 0.50	0.03 0.11	0.01 0.07	0.12 0.20	0.01 0.05
H_3	0.52 ± 0.48	5.81 ± 2.33	-	0.09 ± 0.20	0.51 ± 0.48	3.14 ± 1.74	0.00 ± 0.03	0.02 ± 0.09	0.03 ± 0.10	0.05 ± 0.14	2.09 ± 1.06	3.23 ± 1.28	0.04 ± 0.13	0.02 ± 0.10	0.16 ± 0.26	0.00 ± 0.00	0.00 ± 0.02	0.00 ± 0.00
H_4	4.09 ± 1.38	0.70 ± 0.45	0.23 ± 0.23	-	3.86 ± 2.12	0.38 ± 0.38	1.21 ± 0.67	0.65 ± 0.43	0.03 ± 0.03	0.62 ± 0.41	0.27 ± 0.24	0.04 ± 0.09	1.84 ± 0.77	0.18 ± 0.20	0.03 ± 0.08	0.07 ± 0.13	0.00 ± 0.03	0.01 ± 0.04
H_5	1.24 ± 0.66	1.63 ± 1.02	1.07 ± 0.60	4.98 ± 2.46	-	4.59 ± 2.29	0.26 ± 0.26	0.98 ± 0.66	0.28 ± 0.28	0.14 ± 0.20	0.40 ± 0.32	0.15 ± 0.20	0.18 ± 0.22	1.17 ± 0.58	0.14 ± 0.17	0.00 ± 0.03	0.01 ± 0.06	0.01 ± 0.04
H_6	0.25 ± 0.29	0.78 ± 0.46	4.04 ± 1.37	0.38 ± 0.36	3.79 ± 2.04	-	0.03 ± 0.08	0.62 ± 0.51	1.29 ± 0.86	0.04 ± 0.10	0.30 ± 0.28	0.68 ± 0.44	0.03 ± 0.08	0.22 ± 0.22	1.88 ± 0.91	0.01 ± 0.04	0.01 ± 0.04	0.07 ± 0.13
H_7	0.50 ± 0.57	0.10 ± 0.22	0.05 ± 0.18	6.49 ± 2.38	1.31 ± 0.93	0.13 ± 0.29	-	4.05 ± 2.43	0.25 ± 0.42	0.23 ± 0.34	0.08 ± 0.19	0.02 ± 0.10	1.05 ± 0.74	0.28 ± 0.38	0.02 ± 0.09	1.33 ± 1.00	0.05 ± 0.18	0.00 ± 0.03
H_8	0.32 ± 0.36	0.28 ± 0.36	0.30 ± 0.38	2.22 ± 0.95	3.41 ± 1.41	2.30 ± 1.03	2.50 ± 1.38	-	2.48 ± 1.33	0.12 ± 0.21	0.18 ± 0.26	0.11 ± 0.18	0.31 ± 0.33	0.48 ± 0.40	0.33 ± 0.32	0.07 ± 0.14	0.23 ± 0.25	0.06 ± 0.12
H_9	0.05 ± 0.16	0.22 ± 0.38	0.50 ± 0.65	0.14 ± 0.30	1.33 ± 0.96	6.50 ± 2.69	0.33 ± 0.51	3.98 ± 2.55	-	0.01 ± 0.09	0.16 ± 0.30	0.26 ± 0.37	0.03 ± 0.12	0.25 ± 0.37	1.02 ± 0.80	0.01 ± 0.05	0.05 ± 0.16	1.35 ± 0.96
A_9	1.47 ± 1.06	0.06 ± 0.17	0.01 ± 0.07	1.20 ± 0.92	0.33 ± 0.47	0.03 ± 0.13	0.32 ± 0.44	0.14 ± 0.29	0.03 ± 0.13	-	3.69 ± 2.28	0.27 ± 0.43	6.30 ± 2.40	1.20 ± 0.82	0.14 ± 0.28	0.58 ± 0.65	0.22 ± 0.39	0.03 ± 0.15
A_8	0.07 ± 0.14	0.30 ± 0.33	0.07 ± 0.15	0.34 ± 0.36	0.50 ± 0.35	0.35 ± 0.35	0.14 ± 0.20	0.15 ± 0.24	0.10 ± 0.19	2.36 ± 1.14	-	2.56 ± 1.32	2.22 ± 1.00	3.22 ± 1.34	2.26 ± 1.04	0.27 ± 0.36	0.27 ± 0.36	0.30 ± 0.39
A_7	0.00 ± 0.00	0.06 ± 0.20	1.49 ± 1.00	0.04 ± 0.14	0.29 ± 0.41	1.13 ± 0.82	0.01 ± 0.07	0.10 ± 0.23	0.24 ± 0.37	0.26 ± 0.44	3.81 ± 2.21	-	0.18 ± 0.34	1.30 ± 0.87	6.64 ± 2.48	0.03 ± 0.12	0.10 ± 0.22	0.38 ± 0.48
A_6	0.08 ± 0.13	0.00 ± 0.03	0.02 ± 0.06	2.10 ± 0.85	0.22 ± 0.25	0.03 ± 0.07	0.72 ± 0.44	0.30 ± 0.27	0.05 ± 0.11	1.26 ± 0.75	0.64 ± 0.49	0.03 ± 0.09	-	3.70 ± 2.10	0.36 ± 0.34	4.08 ± 1.42	0.80 ± 0.50	0.23 ± 0.27
A_5	0.01 ± 0.04	0.02 ± 0.07	0.01 ± 0.05	0.17 ± 0.22	1.27 ± 0.54	0.18 ± 0.23	0.14 ± 0.20	0.39 ± 0.33	0.16 ± 0.21	0.24 ± 0.24	1.02 ± 0.66	0.26 ± 0.28	4.58 ± 2.33	-	4.59 ± 2.38	1.04 ± 0.65	1.60 ± 0.96	1.09 ± 0.63
A_4	0.01 ± 0.04	0.00 ± 0.03	0.07 ± 0.12	0.04 ± 0.09	0.19 ± 0.22	1.95 ± 0.80	0.04 ± 0.08	0.24 ± 0.25	0.67 ± 0.42	0.02 ± 0.07	0.58 ± 0.43	1.27 ± 0.67	0.34 ± 0.33	3.77 ± 2.09	-	0.23 ± 0.25	0.67 ± 0.45	3.80 ± 1.41
A_3	0.00 ± 0.02	0.00 ± 0.00	0.00 ± 0.02	0.20 ± 0.30	0.03 ± 0.11	0.01 ± 0.08	3.31 ± 1.36	2.01 ± 0.96	0.07 ± 0.16	0.03 ± 0.11	0.01 ± 0.05	0.01 ± 0.05	3.23 ± 1.66	0.56 ± 0.54	0.06 ± 0.16	-	5.52 ± 2.34	0.55 ± 0.54
A_2	0.02 ± 0.08	0.16 ± 0.27	0.01 ± 0.07	0.10 ± 0.21	0.55 ± 0.48	0.03 ± 0.11	0.25 ± 0.34	6.62 ± 2.01	0.40 ± 0.43	0.03 ± 0.12	0.06 ± 0.16	0.03 ± 0.10	0.62 ± 0.53	1.58 ± 1.03	0.53 ± 0.50	3.28 ± 1.65	-	3.0
A_1	0.00 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.13	0.02 ± 0.09	0.22 ± 0.32	0.04 ± 0.14	1.90 ± 0.95	3.46 ± 1.47	0.01 ± 0.05	0.01 ± 0.08	0.05 ± 0.15	0.08 ± 0.18	0.51 ± 0.49	3.25 ± 1.65	0.49 ± 0.45	5.43 ± 2.18	

4. Calculation Result

4.4 Effect of a change of transition rates

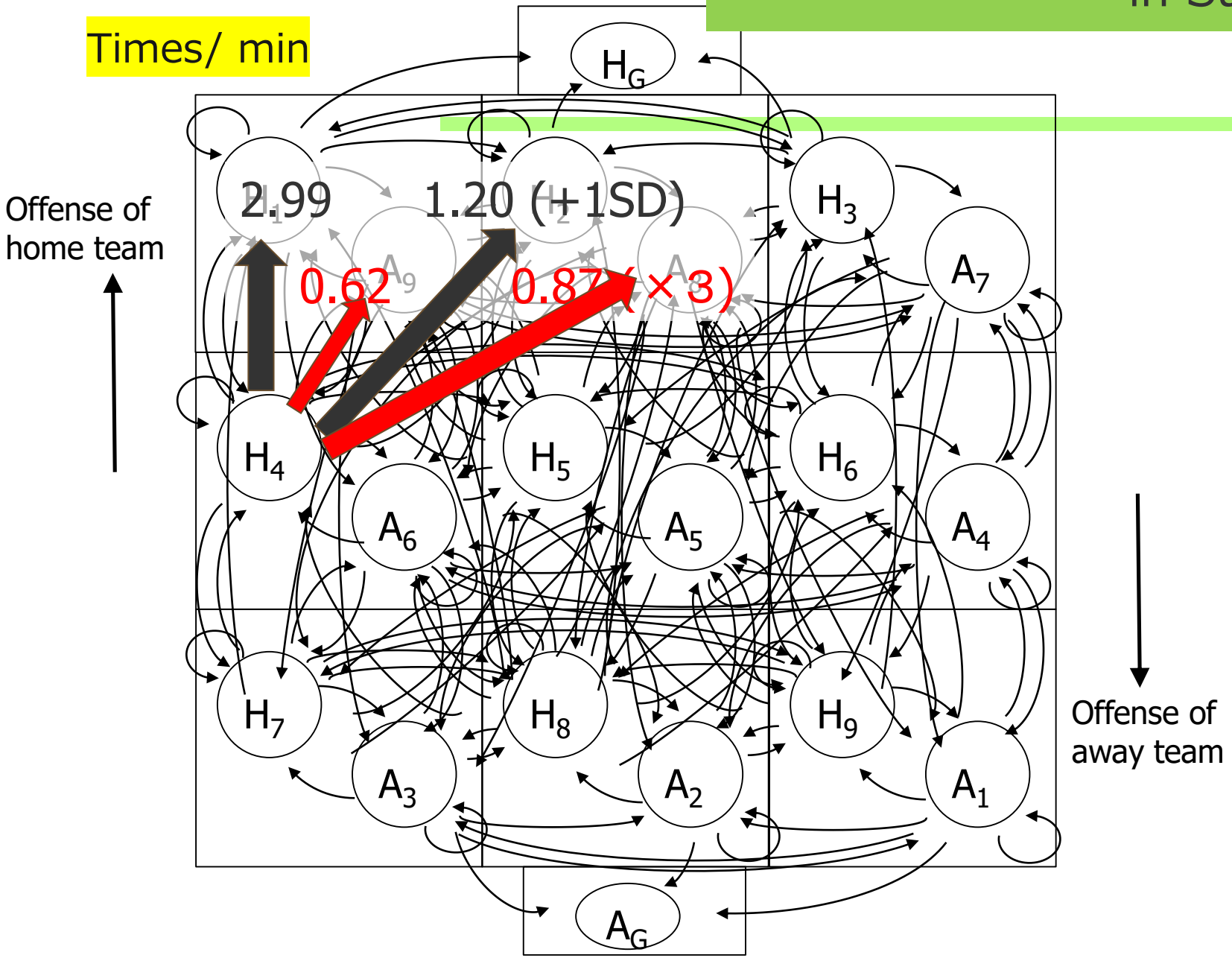
Tactic 0: Base



4. Calculation Result

4.4 Effect of a Change of Transition R

Tactic 1: More aggressive in State H_4



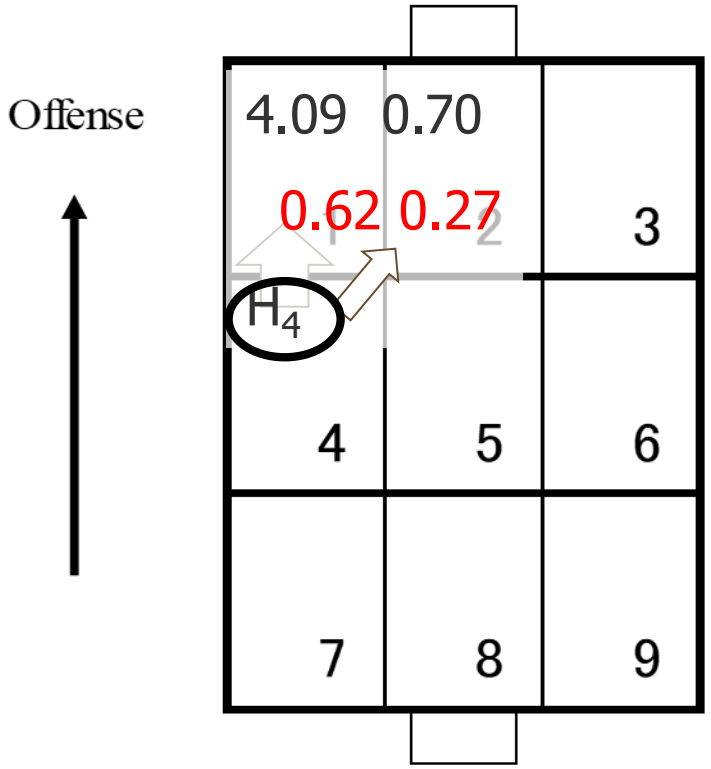
4. Calculation Result

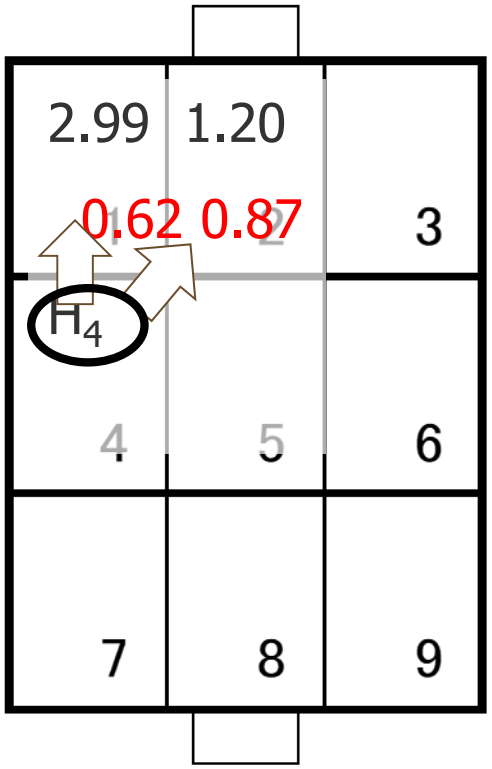
4.4 Effect of a Change of Transition Rates

Transition rates:

Tactic 0: Base

Tactic 1: More aggressive in State H_4



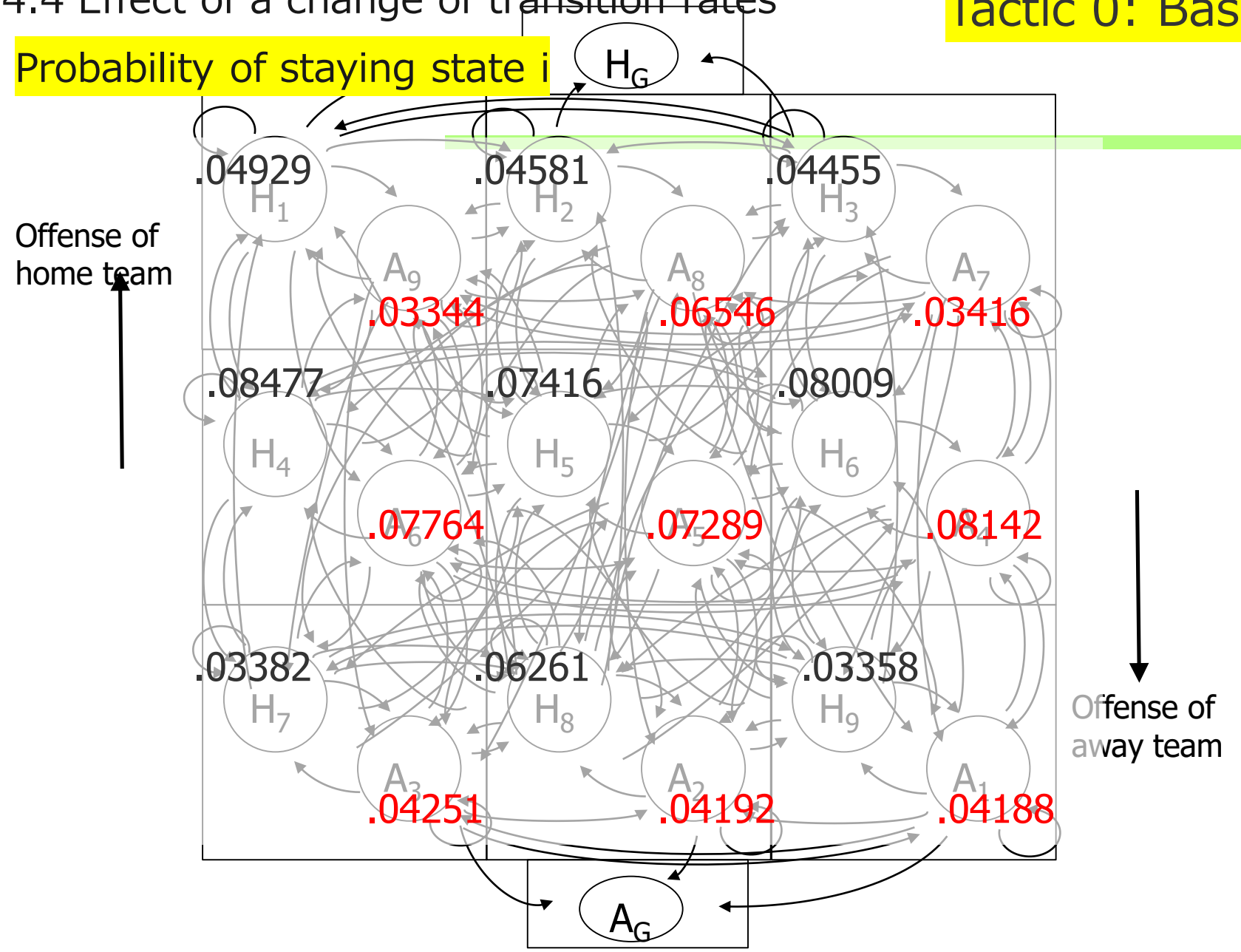


4. Calculation Result

4.4 Effect of a change of transition rates

Tactic 0: Base

Probability of staying state i

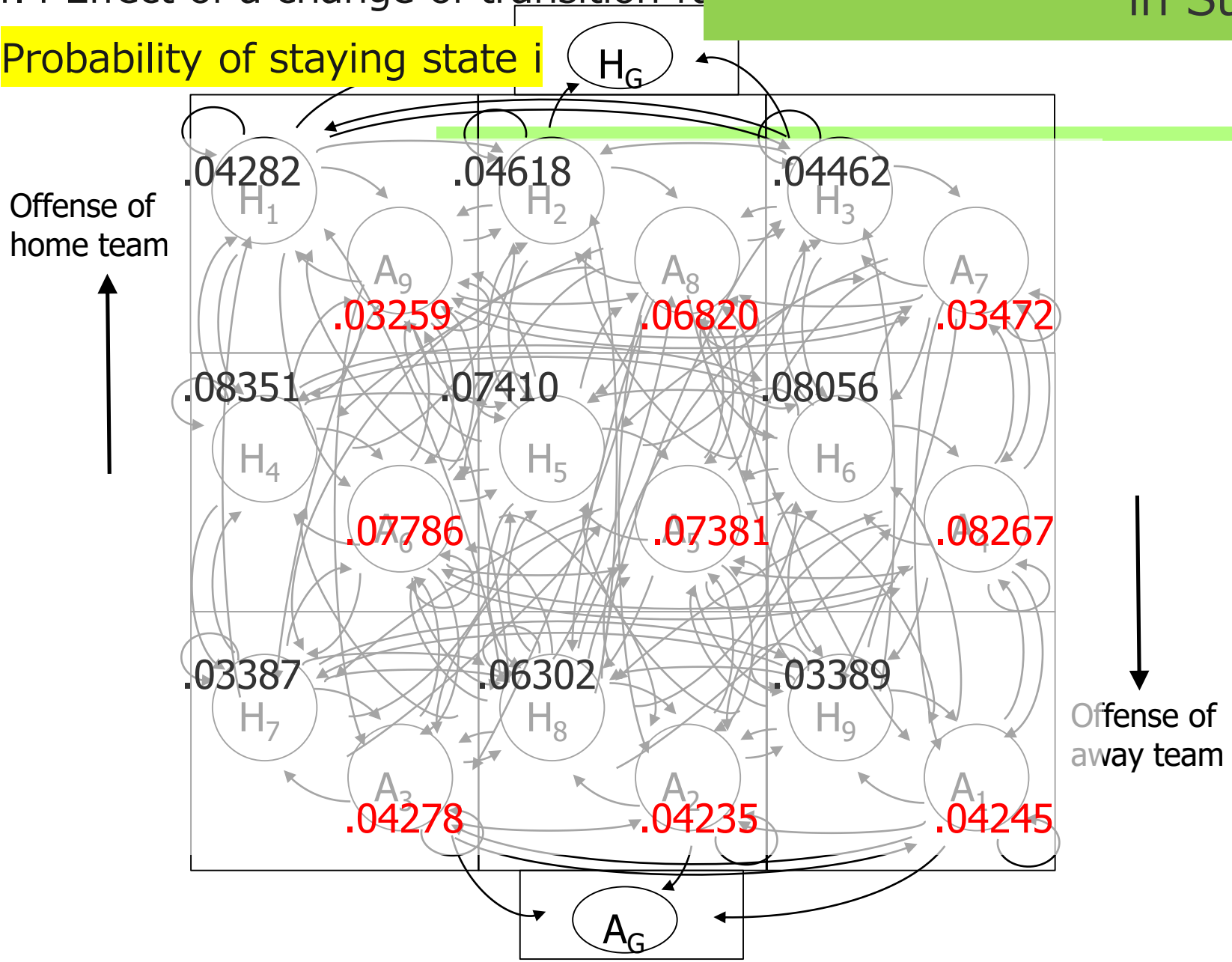


4. Calculation Result

4.4 Effect of a change of transition ra

Tactic 1: More aggressive in State H_4

Probability of staying state i



4. Calculation Result

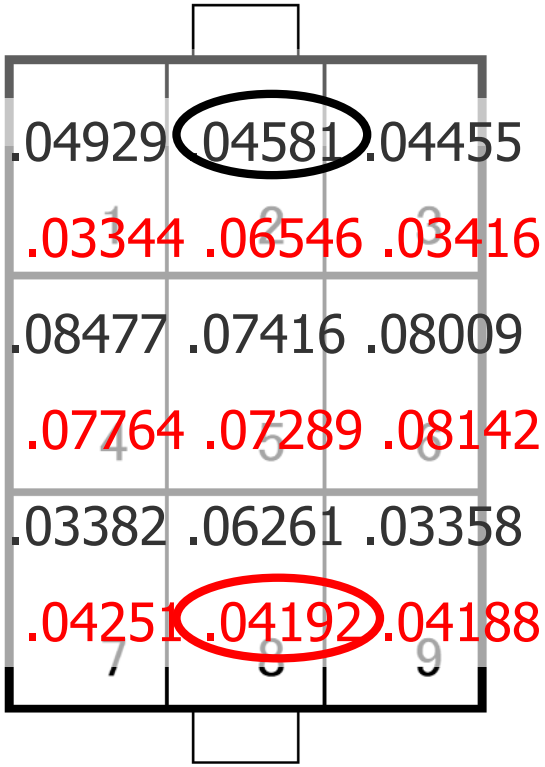
4.4 Effect of a change of transition rates

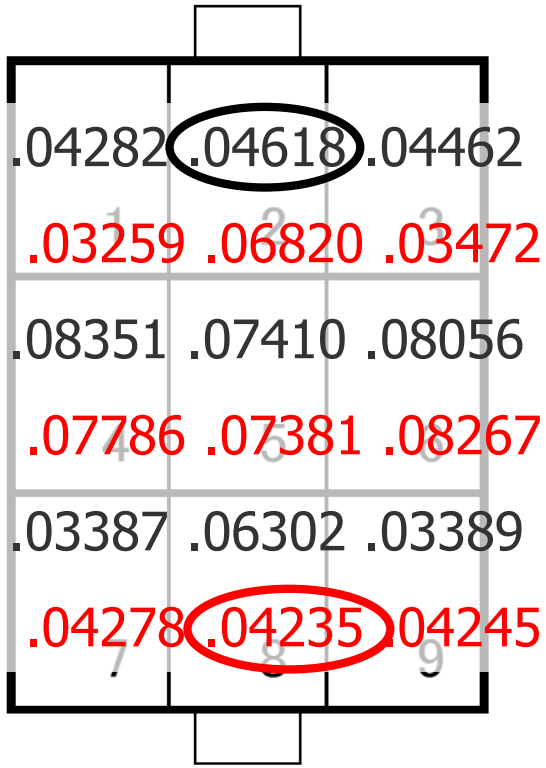
Probability of staying state i:

Tactic 0: Base

Tactic 1: More aggressive in State H_4

Offense of home team





4. Calculation Result

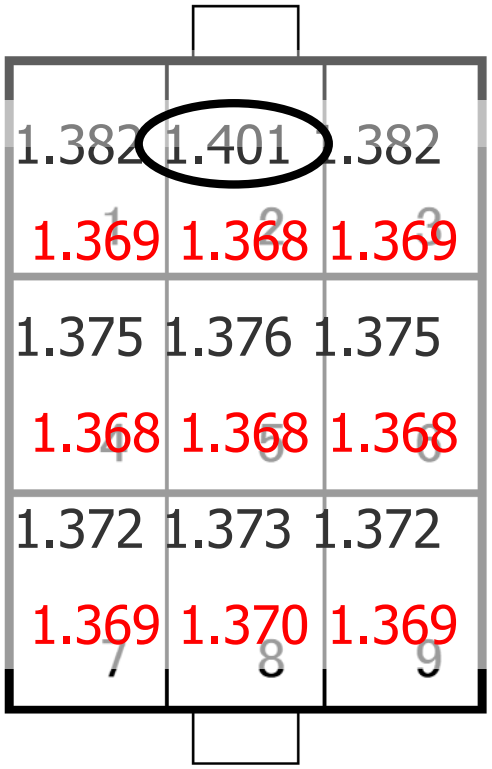
4.4 Effect of a change of transition rates

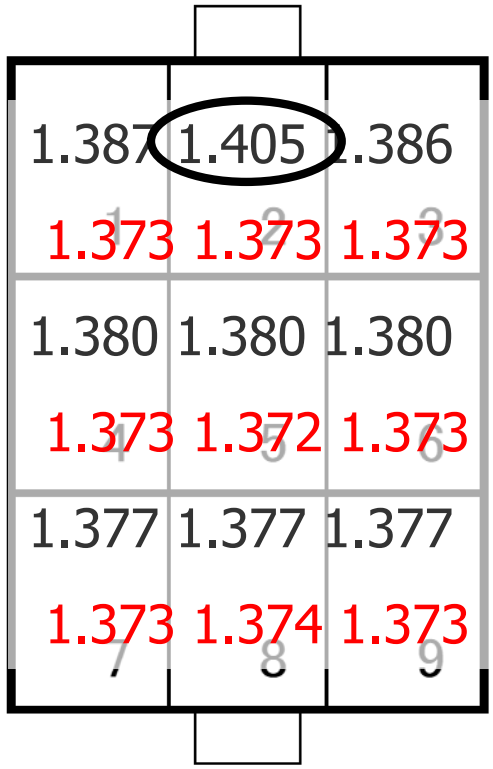
Expected number of goals of home team

Tactic 0: Base

Tactic 1: More aggressive in State H_4

Offense of home team





4. Calculation Result

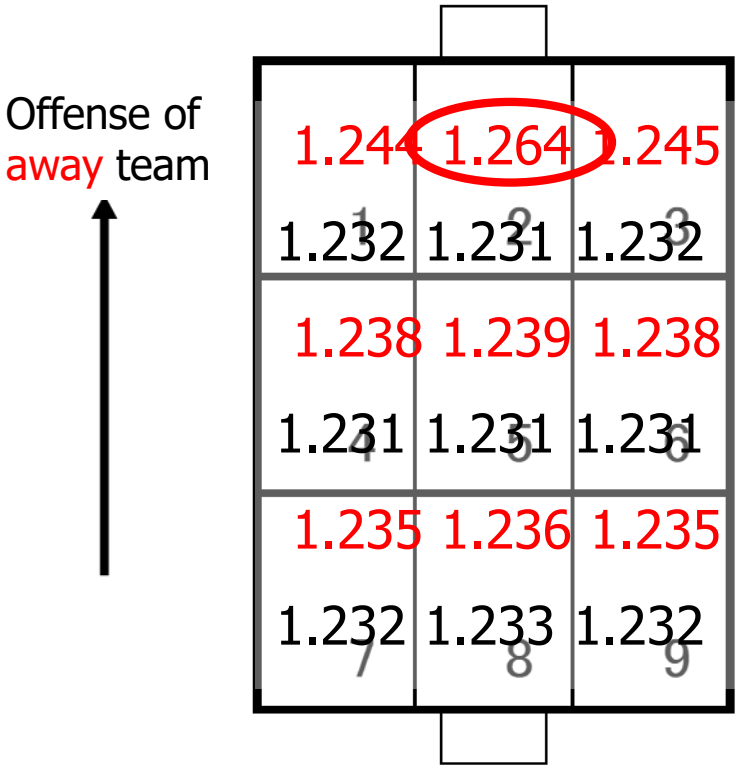
4.4 Effect of a change of transition rates

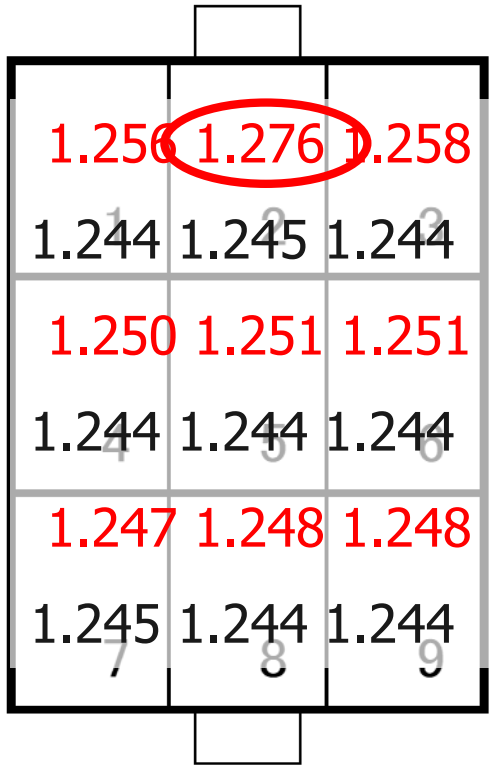
Expected number of goals of away team

Tactic 0: Base

Tactic 1: More aggressive in State H_4

Offense of away team





4. Calculation Result

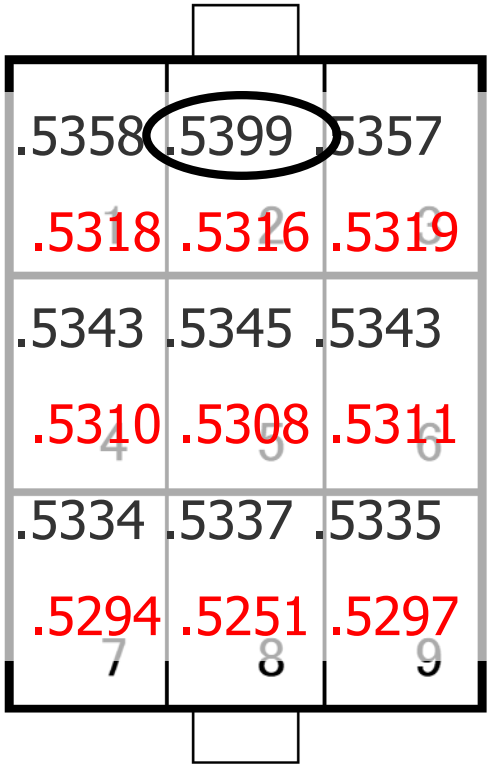
4.4 Effect of a change of transition rates

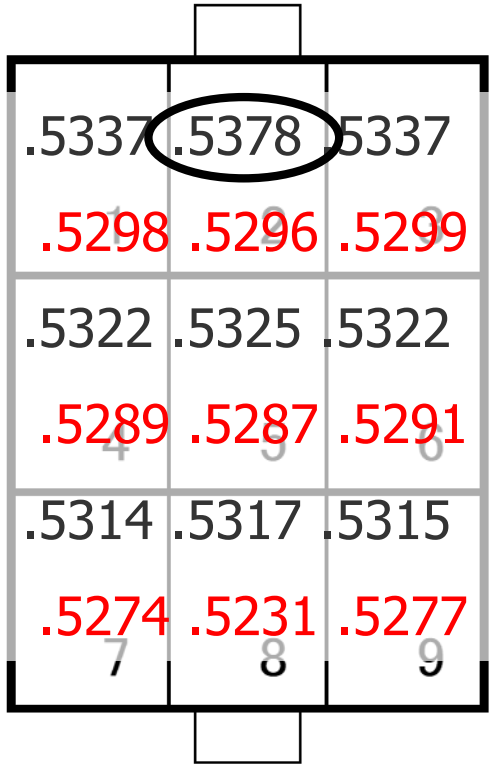
Probability of winning

Tactic 0: Base

Tactic 1: More aggressive in State H_4

Offense of home team





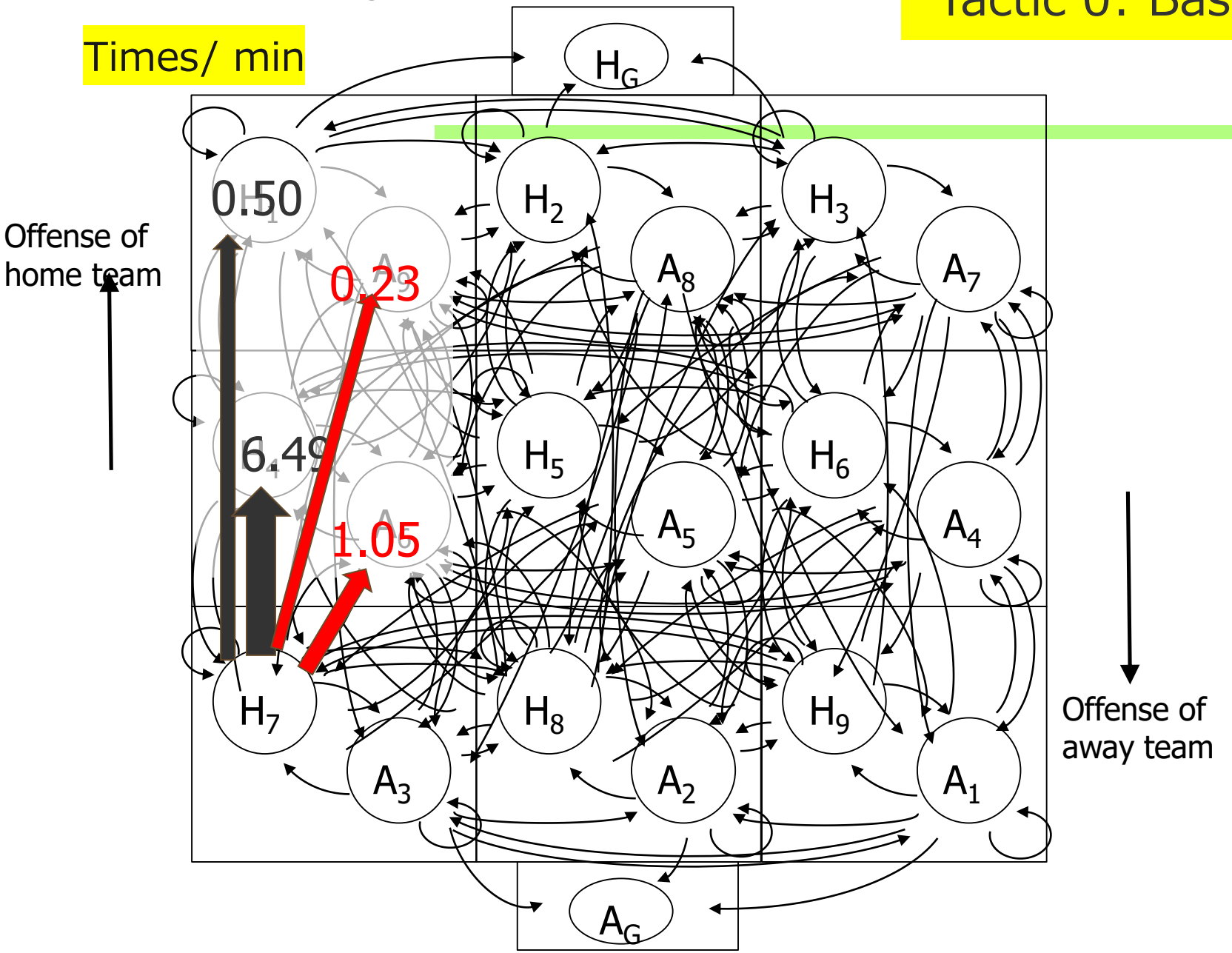
4. Calculation Result 4.4 Effect of a change of transition rates

	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1
H_1	-	5.55 ± 2.28	0.48 ± 0.42	3.09 ± 1.53	0.54 ± 0.51	0.04 ± 0.13	0.05 ± 0.15	0.01 ± 0.07	0.01 ± 0.05	3.12 ± 1.33	1.71 ± 0.85	0.06 ± 0.15	0.21 ± 0.28	0.02 ± 0.09	0.01 ± 0.06	0.00 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
H_2	3.33 ± 1.76	-	3.34 1.71	0.62 0.57	1.50 0.95	0.57 0.53	0.05 0.14	0.04 0.13	0.02 0.09	0.32 0.40	6.81 2.02	0.25 0.30	0.11 0.20	0.59 0.50	0.03 0.11	0.01 0.07	0.12 0.20	0.01 0.05
H_3	0.52 ± 0.48	5.81 ± 2.33	-	0.09 ± 0.20	0.51 ± 0.48	3.14 ± 1.74	0.00 ± 0.03	0.02 ± 0.09	0.03 ± 0.10	0.05 ± 0.14	2.09 ± 1.06	3.23 ± 1.28	0.04 ± 0.13	0.02 ± 0.10	0.16 ± 0.26	0.00 ± 0.00	0.00 ± 0.02	0.00 ± 0.00
H_4	4.09 ± 1.38	0.70 ± 0.45	0.23 ± 0.23	-	3.86 ± 2.12	0.38 ± 0.38	1.21 ± 0.67	0.65 ± 0.43	0.03 ± 0.08	0.62 ± 0.40	0.27 ± 0.24	0.04 ± 0.09	1.84 ± 0.77	0.18 ± 0.20	0.03 ± 0.08	0.07 ± 0.13	0.00 ± 0.03	0.01 ± 0.04
H_5	1.24 ± 0.66	1.63 ± 1.02	1.07 ± 0.60	4.98 ± 2.46	-	4.59 ± 2.29	0.26 ± 0.26	0.98 ± 0.66	0.28 ± 0.28	0.14 ± 0.20	0.40 ± 0.32	0.15 ± 0.20	0.18 ± 0.22	1.17 ± 0.58	0.14 ± 0.17	0.00 ± 0.03	0.01 ± 0.06	0.01 ± 0.04
H_6	0.25 ± 0.29	0.78 ± 0.46	4.04 ± 1.37	0.38 ± 0.36	3.79 ± 2.04	-	0.03 ± 0.08	0.62 ± 0.51	1.29 ± 0.86	0.04 ± 0.10	0.30 ± 0.28	0.68 ± 0.44	0.03 ± 0.08	0.22 ± 0.22	1.88 ± 0.91	0.01 ± 0.04	0.01 ± 0.04	0.07 ± 0.13
H_7	0.50 ± 0.57	0.10 ± 0.22	0.05 ± 0.18	6.49 ± 2.38	1.31 ± 0.93	0.13 ± 0.29	-	4.05 ± 2.43	0.25 ± 0.2	0.23 ± 0.34	0.08 ± 0.19	0.02 ± 0.10	1.05 ± 0.4	0.28 ± 0.38	0.02 ± 0.09	1.33 ± 1.00	0.05 ± 0.18	0.00 ± 0.03
H_8	0.32 ± 0.36	0.28 ± 0.36	0.30 ± 0.38	2.22 ± 0.95	3.41 ± 1.41	2.30 ± 1.03	2.50 ± 1.38	-	2.48 ± 1.33	0.12 ± 0.21	0.18 ± 0.26	0.11 ± 0.18	0.31 ± 0.33	0.48 ± 0.40	0.33 ± 0.32	0.07 ± 0.14	0.23 ± 0.25	0.06 ± 0.12
H_9	0.05 ± 0.16	0.22 ± 0.38	0.50 ± 0.65	0.14 ± 0.30	1.33 ± 0.96	6.50 ± 2.69	0.33 ± 0.51	3.98 ± 2.55	-	0.01 ± 0.09	0.16 ± 0.30	0.26 ± 0.37	0.03 ± 0.12	0.25 ± 0.37	1.02 ± 0.80	0.01 ± 0.05	0.05 ± 0.16	1.35 ± 0.96
A_9	1.47 ± 1.06	0.06 ± 0.17	0.01 ± 0.07	1.20 ± 0.92	0.33 ± 0.47	0.03 ± 0.13	0.32 ± 0.44	0.14 ± 0.29	0.03 ± 0.13	-	3.69 ± 2.28	0.27 ± 0.43	6.30 ± 2.40	1.20 ± 0.82	0.14 ± 0.28	0.58 ± 0.65	0.22 ± 0.39	0.03 ± 0.15
A_8	0.07 ± 0.14	0.30 ± 0.33	0.07 ± 0.15	0.34 ± 0.36	0.50 ± 0.35	0.35 ± 0.35	0.14 ± 0.20	0.15 ± 0.24	0.10 ± 0.19	2.36 ± 1.14	-	2.56 ± 1.32	2.22 ± 1.00	3.22 ± 1.34	2.26 ± 1.04	0.27 ± 0.36	0.27 ± 0.36	0.30 ± 0.39
A_7	0.00 ± 0.00	0.06 ± 0.20	1.49 ± 1.00	0.04 ± 0.14	0.29 ± 0.41	1.13 ± 0.82	0.01 ± 0.07	0.10 ± 0.23	0.24 ± 0.37	0.26 ± 0.44	3.81 ± 2.21	-	0.18 ± 0.34	1.30 ± 0.87	6.64 ± 2.48	0.03 ± 0.12	0.10 ± 0.22	0.38 ± 0.48
A_6	0.08 ± 0.13	0.00 ± 0.03	0.02 ± 0.06	2.10 ± 0.85	0.22 ± 0.25	0.03 ± 0.07	0.72 ± 0.44	0.30 ± 0.27	0.05 ± 0.11	1.26 ± 0.75	0.64 ± 0.49	0.03 ± 0.09	-	3.70 ± 2.10	0.36 ± 0.34	4.08 ± 1.42	0.80 ± 0.50	0.23 ± 0.27
A_5	0.01 ± 0.04	0.02 ± 0.07	0.01 ± 0.05	0.17 ± 0.22	1.27 ± 0.54	0.18 ± 0.23	0.14 ± 0.20	0.39 ± 0.33	0.16 ± 0.21	0.24 ± 0.24	1.02 ± 0.66	0.26 ± 0.28	4.58 ± 2.33	-	4.59 ± 2.38	1.04 ± 0.65	1.60 ± 0.96	1.09 ± 0.63
A_4	0.01 ± 0.04	0.00 ± 0.03	0.07 ± 0.12	0.04 ± 0.09	0.19 ± 0.22	1.95 ± 0.80	0.04 ± 0.08	0.24 ± 0.25	0.67 ± 0.42	0.02 ± 0.07	0.58 ± 0.43	1.27 ± 0.67	0.34 ± 0.33	3.77 ± 2.09	-	0.23 ± 0.25	0.67 ± 0.45	3.80 ± 1.41
A_3	0.00 ± 0.02	0.00 ± 0.00	0.00 ± 0.02	0.20 ± 0.30	0.03 ± 0.11	0.01 ± 0.08	3.31 ± 1.36	2.01 ± 0.96	0.07 ± 0.16	0.03 ± 0.11	0.01 ± 0.05	0.01 ± 0.05	3.23 ± 1.66	0.56 ± 0.54	0.06 ± 0.16	-	5.52 ± 2.34	0.55 ± 0.54
A_2	0.02 ± 0.08	0.16 ± 0.27	0.01 ± 0.07	0.10 ± 0.21	0.55 ± 0.48	0.03 ± 0.11	0.25 ± 0.34	6.62 ± 2.01	0.40 ± 0.43	0.03 ± 0.12	0.06 ± 0.16	0.03 ± 0.10	0.62 ± 0.53	1.58 ± 1.03	0.53 ± 0.50	3.28 ± 1.65	-	3.0
A_1	0.00 ± 0.04	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.13	0.02 ± 0.09	0.22 ± 0.32	0.04 ± 0.14	1.90 ± 0.95	3.46 ± 1.47	0.01 ± 0.05	0.01 ± 0.08	0.05 ± 0.15	0.08 ± 0.18	0.51 ± 0.49	3.25 ± 1.65	0.49 ± 0.45	5.43 ± 2.18	

4. Calculation Result

4.4 Effect of a change of transition rates

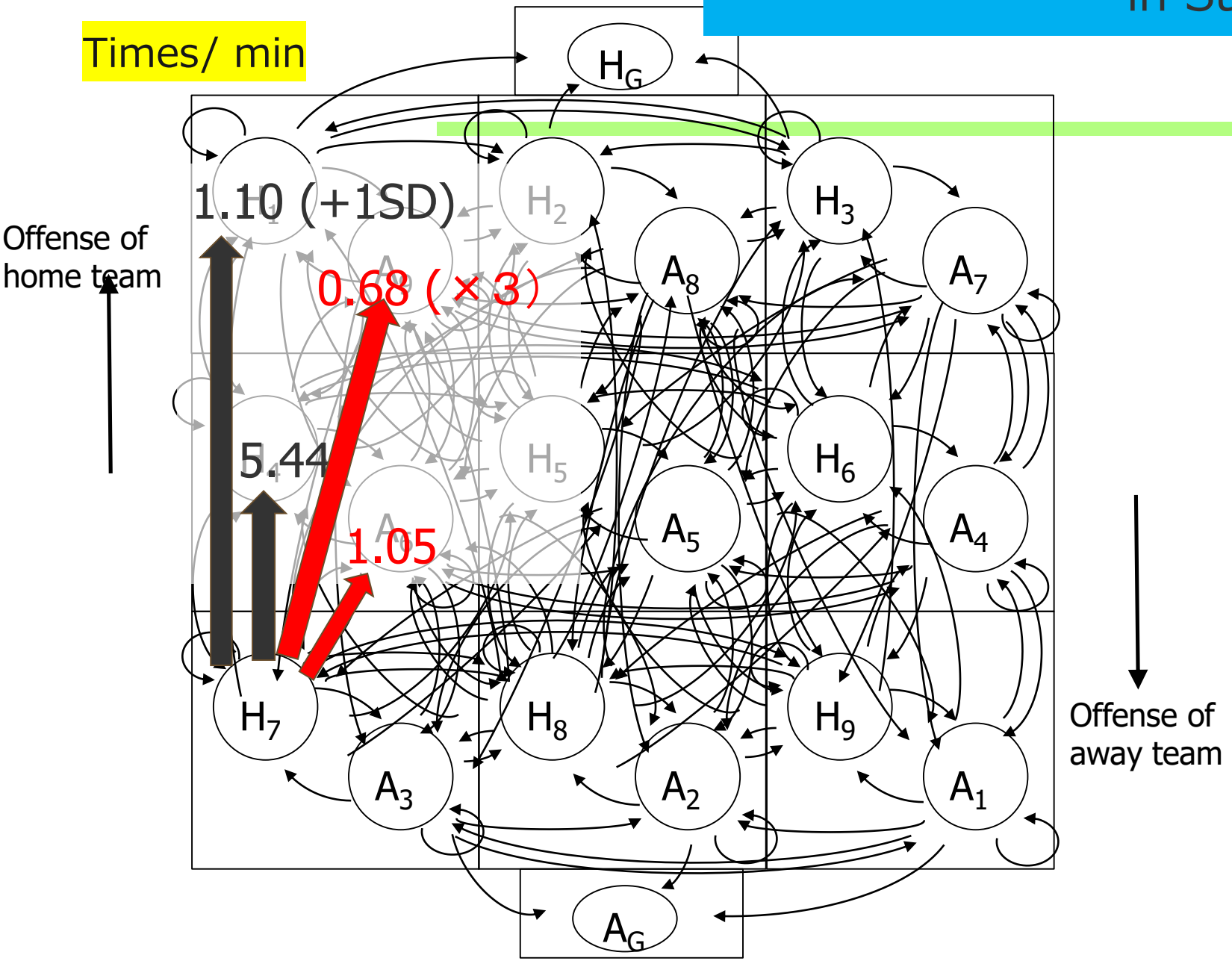
Tactic 0: Base



4. Calculation Result

4.4 Effect of a change of transition ra

Tactic 2: More aggressive in State H_7



4. Calculation Result

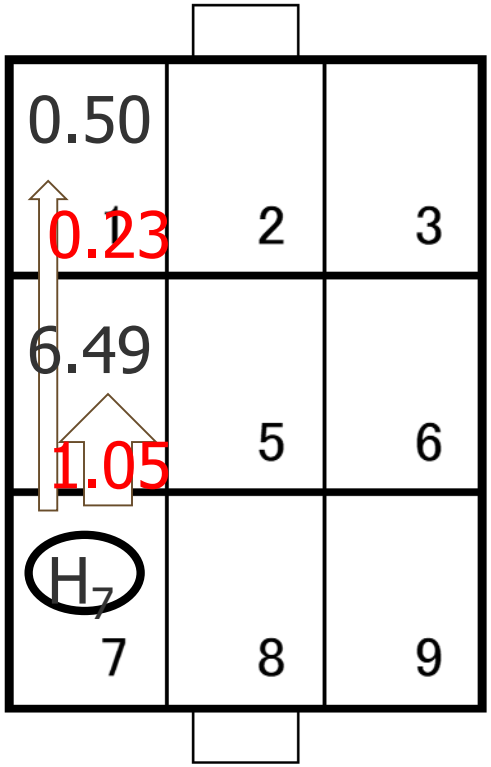
4.4 Effect of a change of transition rates

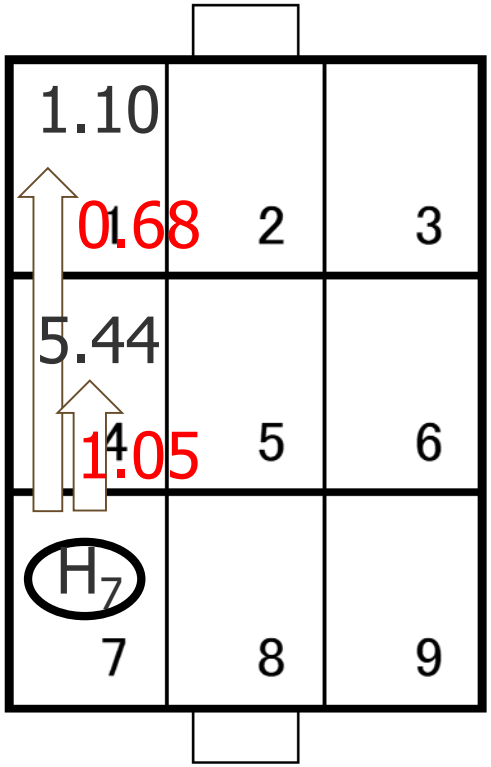
Transition rates:

Tactic 0: Base

Tactic 2: More aggressive in State H_7

Offense of home team





4. Calculation Result

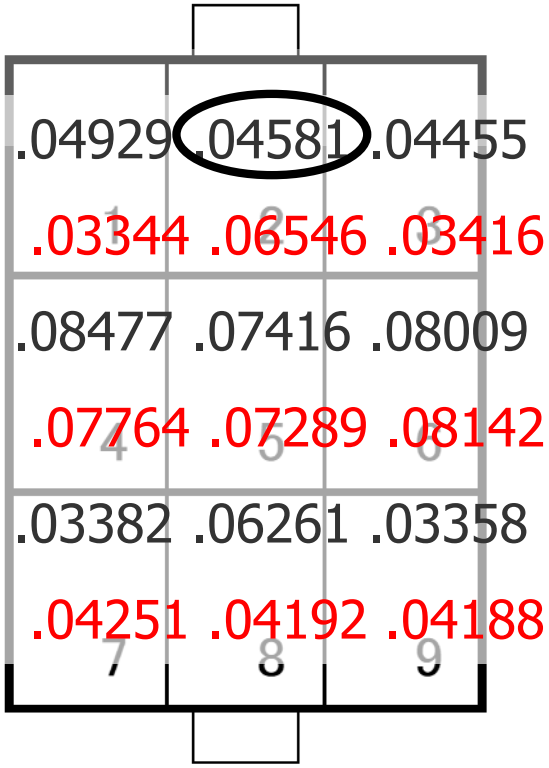
4.4 Effect of a change of transition rates

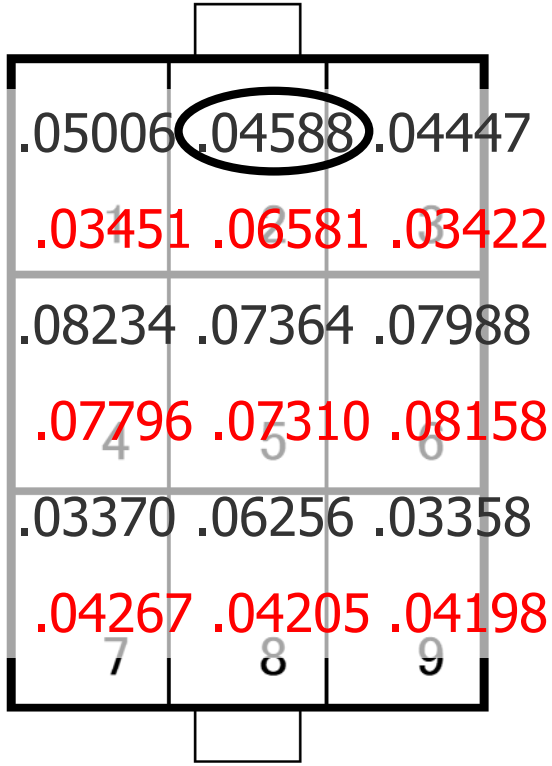
Probability of staying state i

Tactic 0: Base

Tactic 2: More aggressive in State H_7

Offense of home team





55.17

4. Calculation Result

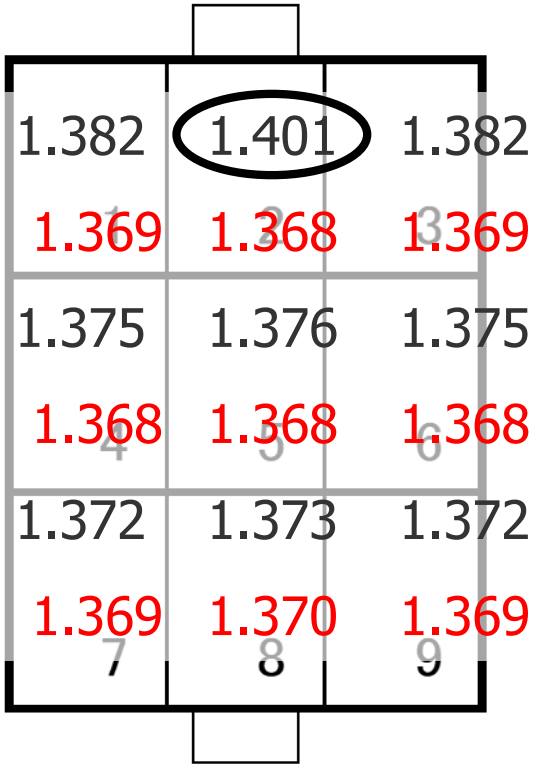
4.4 Effect of a change of transition rates

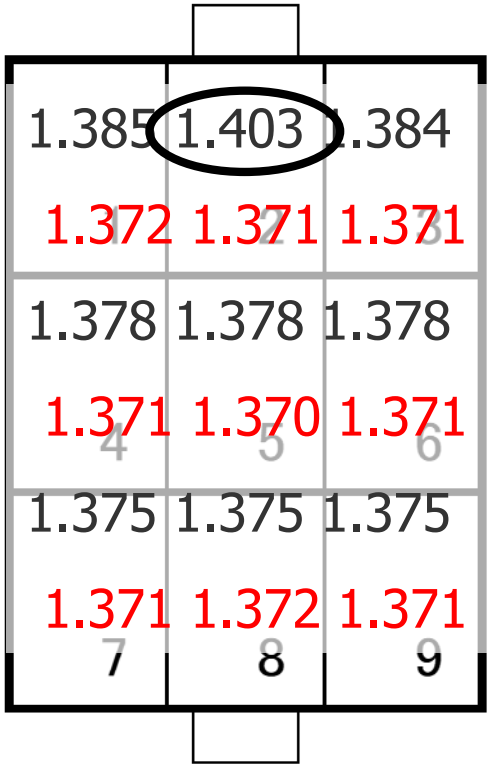
Expected number of goals of home team

Tactic 0: Base

Tactic 2: More aggressive in State H_7

Offense of home team





4. Calculation Result

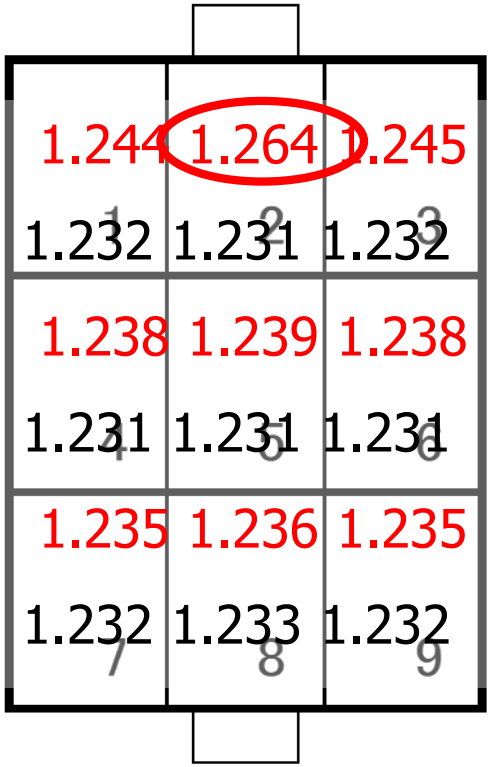
4.4 Effect of a change of transition rates

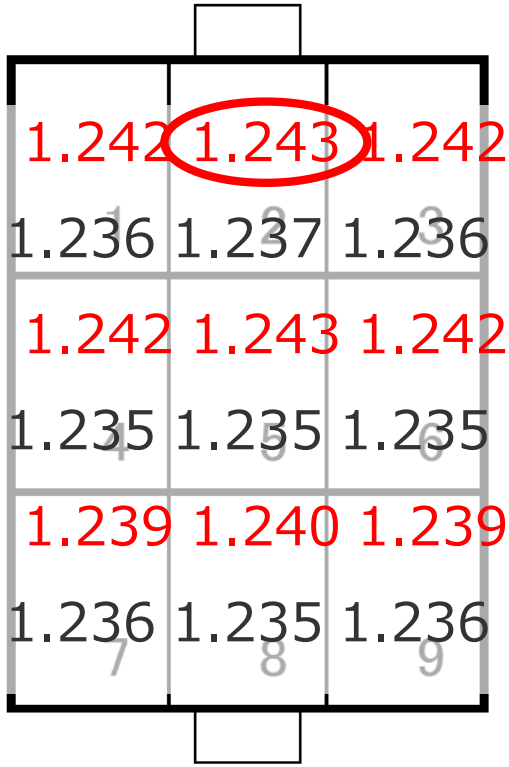
Expected number of goals of away team

Tactic 0: Base

Tactic 2: More aggressive in State H_7

Offense of away team





4. Calculation Result

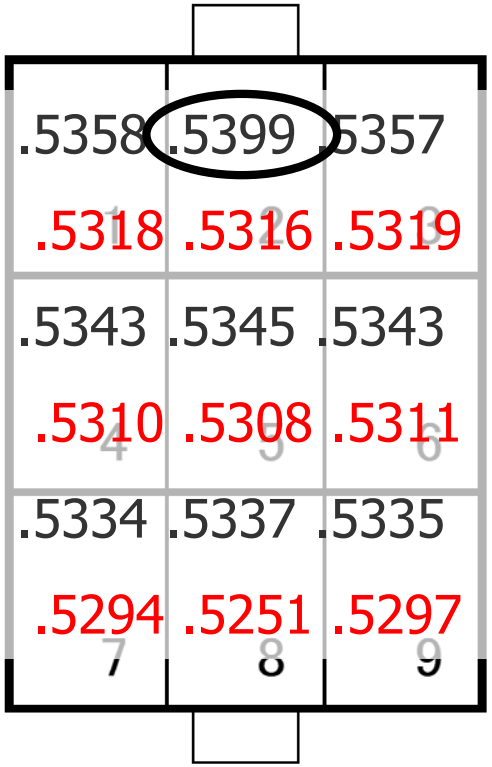
4.4 Effect of a change of transition rates

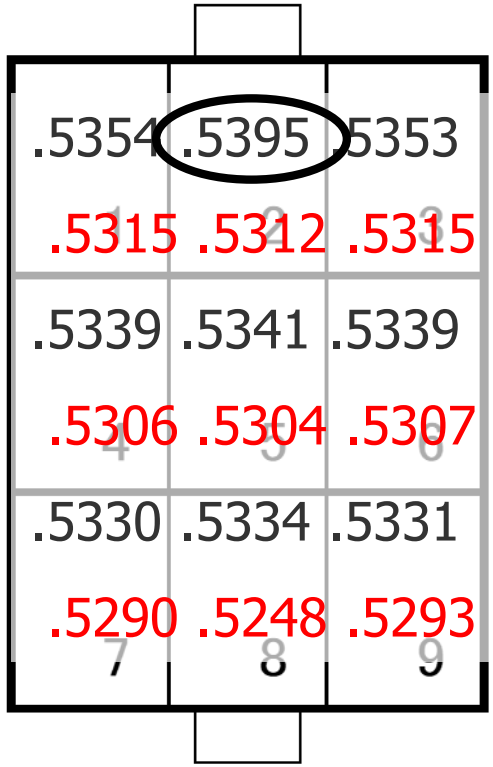
Probability of winning

Tactic 0: Base

Tactic 2: More aggressive in State H_7

Offense of home team



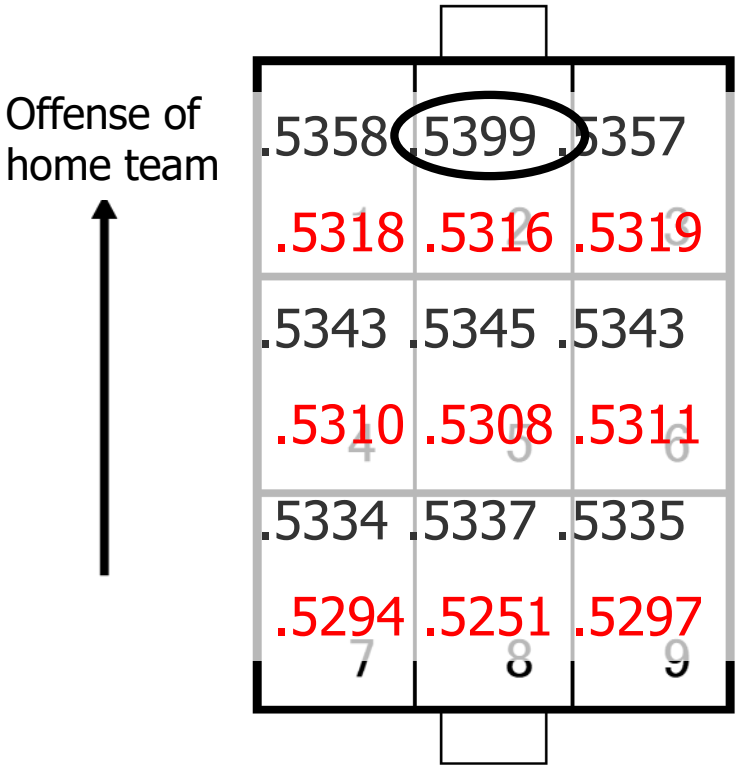


4. Calculation Result

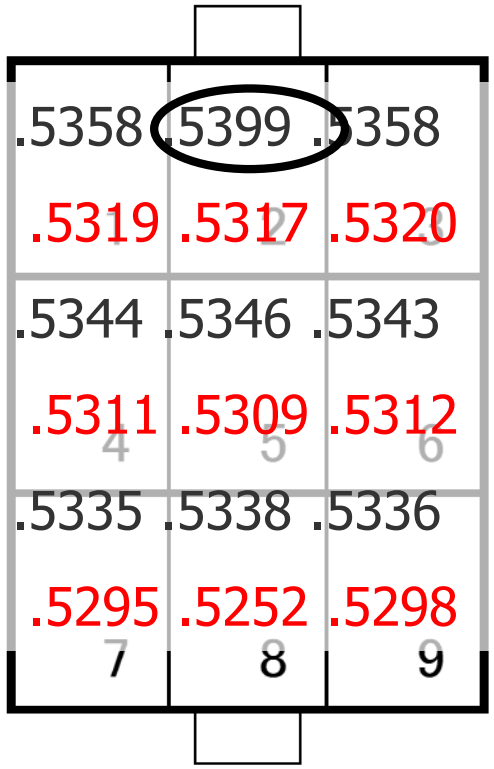
4.4 Effect of a change of transition rates

Probability of winning

Tactic 0



Tactic 0 & Tactic 1



4. Calculation Result

4.4 Effect of a change of transition rates

Timing to use Tactic 0 and Tactic 1

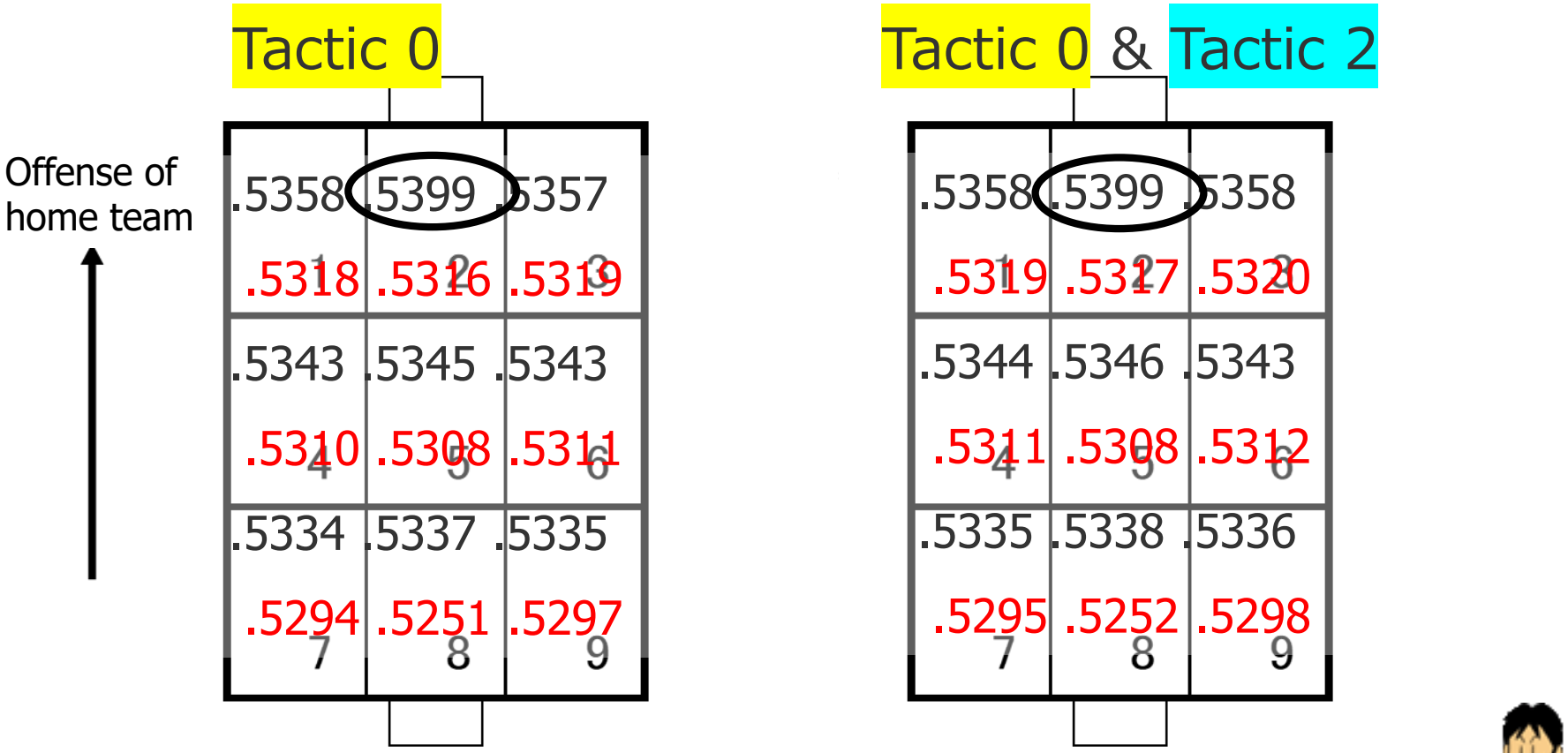
For maximizing the probability of winning

		Lead by home team				
Net Time	Time	−2	−1	0	1	2
0	0	0	0	0	0	0
3.1	5	0	0	0	0	0
6.1	10	0	0	0	0	0
9.2	15	0	0	0	0	0
12.3	20	0	0	0	0	0
15.3	25	0	0	0	0	0
18.4	30	0	0	0	0	0
21.5	35	0	0	0	0	0
24.5	40	0	0	0	0	0
27.6	45	0	0	0	0	0
30.7	50	1	0	0	0	0
33.7	55	1	0	0	0	0
36.8	60	1	0	0	0	0
39.8	65	1	1	0	0	0
42.9	70	1	1	0	0	0
46.0	75	1	1	0	0	0
49.0	80	1	1	0	0	0
52.1	85	1	1	0	0	0
55.17	90	1	1	0	0	0

4. Calculation Result

4.4 Effect of a change of transition rates

Probability of winning



4. Calculation Result

4.4 Effect of a change of transition rates

Timing to use Tactic 0 and Tactic 2

For maximizing the probability of winning

		Lead by home team				
Net Time	Time	−2	−1	0	1	2
0	0	2	0	0	0	0
3.1	5	2	0	0	0	0
6.1	10	2	0	0	0	0
9.2	15	2	0	0	0	0
12.3	20	2	0	0	0	0
15.3	25	2	2	0	0	0
18.4	30	2	2	0	0	0
21.5	35	2	2	0	0	0
24.5	40	2	2	0	0	0
27.6	45	2	2	0	0	0
30.7	50	2	2	0	0	0
33.7	55	2	2	0	0	0
36.8	60	2	2	0	0	0
39.8	65	2	2	0	0	0
42.9	70	2	2	0	0	0
46.0	75	2	2	0	0	0
49.0	80	2	2	0	0	0
52.1	85	2	2	0	0	0
55.17	90	2	2	0	0	0

4. Calculation Result

4.4 Effect of a change of transition rates

Use Tactic 0, 1, 2

Probability of winning

Tactic 0

Offense of home team

.5358	.5399	.5357
.5318 (1)	.5316 (2)	.5319 (3)
.5343	.5345	.5343
.5310 (4)	.5308 (5)	.5311 (6)
.5334	.5337	.5335
.5294 (7)	.5251 (8)	.5297 (9)

Tactic 0 & 1 & 2

.5359	.5400	.5359
.5320 (1)	.5318 (2)	.5321 (3)
.5344	.5347	.5344
.5311 (4)	.5309 (5)	.5312 (6)
.5336	.5339	.5337
.5295 (7)	.5253 (8)	.5299 (9)

4. Calculation Result

4.4 Effect of a change of transition rates

Timing to use Tactic 0, 1, 2

For maximizing the probability of winning

		Lead by home team				
Net Time	Time	−2	−1	0	1	2
0	0	2	0	0	0	0
3.1	5	2	0	0	0	0
6.1	10	2	0	0	0	0
9.2	15	2	0	0	0	0
12.3	20	2	0	0	0	0
15.3	25	2	2	0	0	0
18.4	30	2	2	0	0	0
21.5	35	2	2	0	0	0
24.5	40	1,2	2	0	0	0
27.6	45	1,2	2	0	0	0
30.7	50	1,2	2	0	0	0
33.7	55	1,2	2	0	0	0
36.8	60	1,2	2	0	0	0
39.8	65	1,2	1,2	0	0	0
42.9	70	1,2	1,2	0	0	0
46.0	75	1,2	1,2	0	0	0
49.0	80	1,2	1,2	0	0	0
52.1	85	1,2	1,2	0	0	0
55.17	90	1,2	1,2	0	0	0

JUNTENDO

5. Further work

Finding the effects of other changes of transition rates

Estimate the transition rates using log-linear models which explain such factors as home advantage, offensive and defensive strength, in terms of goals and possession, according to the location

Analyze using hierarchical / multi-level model

Application of Markov process model will provide more insight into the football match analysis.

6. Conclusions

1. Introduction: Analyze t change of transition probabilit a goal or winning a match.
2. Markov process model ame:
   - Dividing the pitch into
   - Calculation of probabi time, probability distribution, probability of winning
   - Dynamic programmin for maximizing the PW
3. Estimation of transition
   - Annual data from J-Le 1 in 2015
   - Play by play data → fr time of transitions
4. Calculation Result:
   - Probability of staying s tive error : <3%
   - Effect of a change of tr s is estimated.
5. Further work: Analyze other effects of the change of transition rates

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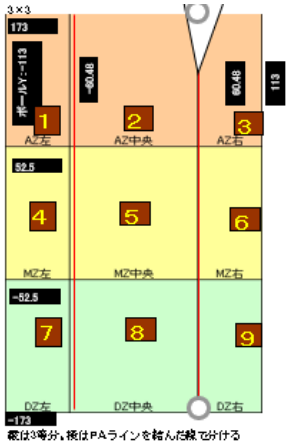
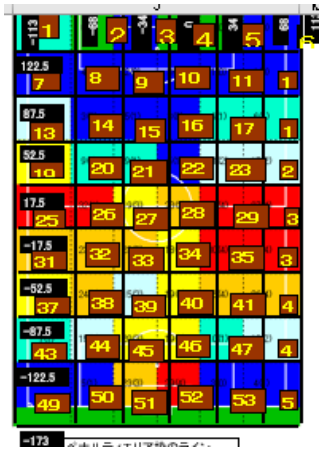


縦は3等分、横はPAラインを結んだ線で分ける



4. Calculation Result

4.2 Probability distribution of the number of goals

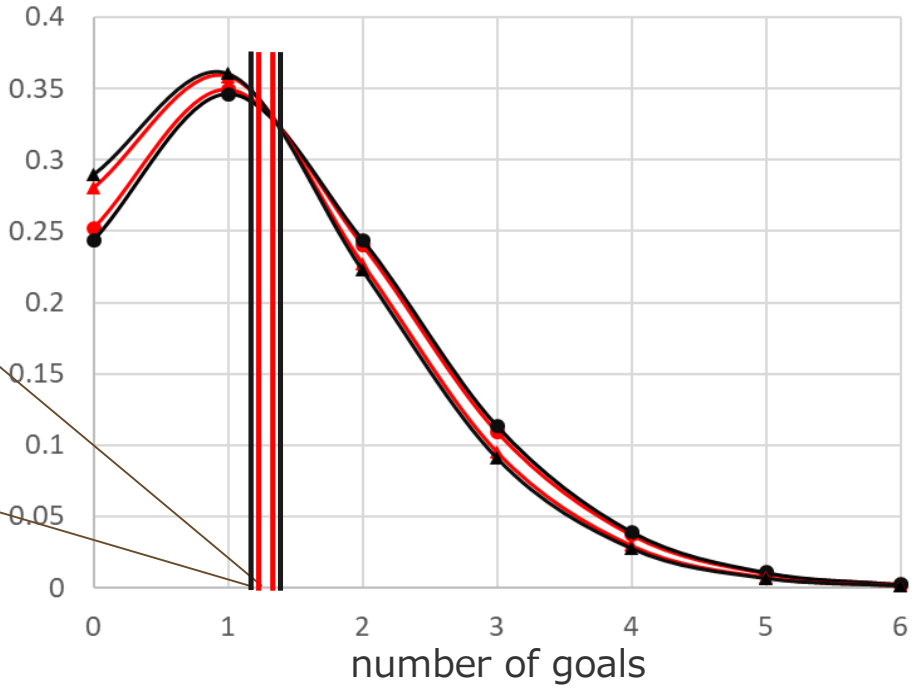
Calculation result in terms of the probability distribution of the number of goals by **away team**

Expected number of goals

Offense of away team

1.244	1.264	1.245
1.232	1.231	1.232
1.238	1.239	1.238
1.231	1.231	1.231
1.235	1.236	1.235
1.232	1.233	1.232

Probability distribution



4. Numerical Result

Table 4: Calculation result in terms of the probability distribution of sco
goals, the expected number of goals, and the probability of winning

				+1SD		-1SD	
				H_4H_1	H_7H_4	H_4A_9	H_7A_6
Goals	H_2	H_5	H_8	H_5	H_5	H_5	H_5
0	0.244	0.250	0.251	0.240	0.247	0.247	0.248
1	0.346	0.348	0.349	0.344	0.347	0.347	0.348
2	0.244	0.241	0.240	0.245	0.242	0.242	0.242
3	0.114	0.110	0.109	0.116	0.112	0.112	0.111
4	0.039	0.038	0.037	0.041	0.038	0.038	0.038
Exp. Num.	1.401	1.376	1.370	1.417	1.388	1.388	1.382
Prob. Win.	0.540	0.535	0.534	0.543	0.538	0.539	0.538

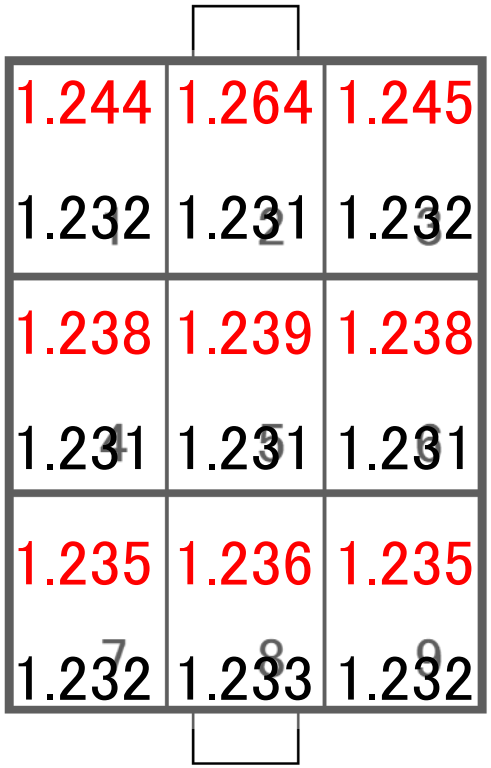
4. Calculation Result

4.4 Effect of a Change of Transition Probabilities

Probability distribution of the number of goals

Base → Tactic 1: More aggressive in State H4

Offense of away team



1.256 1.276 1.258

1.244 1.244 1.245

1.250 1.251 1.251

1.244 1.244 1.244

1.247 1.248 1.248

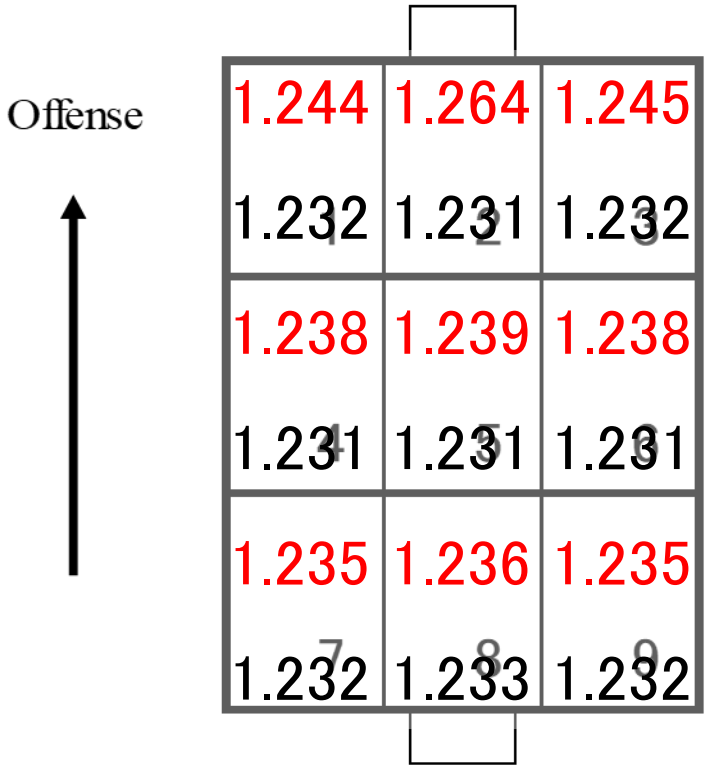
1.244 1.245 1.244

4. Calculation Result

4.4 Effect of a Change of Transition Probabilities

Probability distribution of the number of goals scored by the way team

Tactic 2: More aggressive in State H7



1.248 1.268 1.249

1.236 1.235 1.236

1.242 1.243 1.242

1.235 1.235 1.235

1.239 1.240 1.239

1.236 1.237 1.236

4. Numerical Example

4.2 Estimation of Transition Rates

Table 3: Transition rates between states (Mean & (SD))

↗	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1
H_1		5.6 (2.3)	0.5 (0.4)	3.1 (1.5)	0.5 (0.5)	0.0 (0.1)	0.1 (0.2)	0.0 (0.1)	0.0 (0.0)	3.1 (1.3)	1.7 (0.9)	0.1 (0.1)	0.2 (0.3)	0.0 (0.1)	0.0 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
H_2	3.3 (1.8)		3.3 (1.7)	0.6 (0.6)	1.5 (1.0)	0.6 (0.5)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.3 (0.4)	6.8 (2.0)	0.3 (0.3)	0.1 (0.2)	0.6 (0.5)	0.0 (0.1)	0.0 (0.1)	0.1 (0.2)	0.0 (0.1)
H_3	0.5 (0.5)	5.8 (2.3)		0.1 (0.2)	0.5 (0.5)	3.1 (1.7)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	2.1 (1.1)	3.2 (1.3)	0.0 (0.1)	0.0 (0.1)	0.2 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
H_4	4.1 (1.4)	0.7 (0.5)	0.2 (0.2)		3.9 (2.1)	0.4 (0.4)	1.2 (0.7)	0.6 (0.4)	0.0 (0.1)	0.6 (0.4)	0.3 (0.2)	0.0 (0.1)	1.8 (0.8)	0.2 (0.2)	0.0 (0.1)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)
H_5	1.2 (0.7)	1.6 (1.0)	1.1 (0.6)	5.0 (2.5)		4.6 (2.3)	0.3 (0.3)	1.0 (0.7)	0.3 (0.3)	0.1 (0.2)	0.4 (0.3)	0.2 (0.2)	0.2 (0.2)	1.2 (0.6)	0.1 (0.2)	0.0 (0.0)	0.0 (0.1)	0.0 (0.0)
H_6	0.3 (0.3)	0.8 (0.5)	4.0 (1.4)	0.4 (0.4)	3.8 (2.0)		0.0 (0.1)	0.6 (0.5)	1.3 (0.9)	0.0 (0.1)	0.3 (0.3)	0.7 (0.4)	0.0 (0.1)	0.2 (0.2)	1.9 (0.9)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)
H_7	0.5 (0.6)	0.1 (0.2)	0.0 (0.2)	6.5 (2.4)	1.3 (0.9)	0.1 (0.3)		4.1 (2.4)	0.2 (0.4)	0.2 (0.3)	0.1 (0.2)	0.0 (0.1)	1.0 (0.7)	0.3 (0.4)	0.0 (0.1)	1.3 (1.0)	0.1 (0.2)	0.0 (0.0)
H_8	0.3 (0.4)	0.3 (0.4)	0.3 (0.4)	2.2 (0.9)	3.4 (1.4)	2.3 (1.0)	2.5 (1.4)		2.5 (1.3)	0.1 (0.2)	0.2 (0.3)	0.1 (0.2)	0.3 (0.3)	0.5 (0.4)	0.3 (0.3)	0.1 (0.1)	0.2 (0.2)	0.1 (0.1)
H_9	0.0 (0.2)	0.2 (0.4)	0.5 (0.7)	0.1 (0.3)	1.3 (1.0)	6.5 (2.7)	0.3 (0.5)	4.0 (2.5)		0.0 (0.1)	0.2 (0.3)	0.3 (0.4)	0.0 (0.1)	0.2 (0.4)	1.0 (0.8)	0.0 (0.1)	0.0 (0.2)	1.3 (1.0)
A_9	1.5 (1.1)	0.1 (0.2)	0.0 (0.1)	1.2 (0.9)	0.3 (0.5)	0.0 (0.1)	0.3 (0.4)	0.1 (0.3)	0.0 (0.1)		3.7 (2.3)	0.3 (0.4)	6.3 (2.4)	1.2 (0.8)	0.1 (0.3)	0.6 (0.6)	0.2 (0.4)	0.0 (0.2)
A_8	0.1 (0.1)	0.3 (0.3)	0.1 (0.1)	0.3 (0.4)	0.5 (0.3)	0.3 (0.3)	0.1 (0.2)	0.2 (0.2)	0.1 (0.2)	2.4 (1.1)		2.6 (1.3)	2.2 (1.0)	3.2 (1.3)	2.3 (1.0)	0.3 (0.4)	0.3 (0.4)	0.3 (0.4)
A_7	0.0 (0.0)	0.1 (0.2)	1.5 (1.0)	0.0 (0.1)	0.3 (0.4)	1.1 (0.8)	0.0 (0.1)	0.1 (0.2)	0.2 (0.4)	0.3 (0.4)	3.8 (2.2)		0.2 (0.3)	1.3 (0.9)	6.6 (2.5)	0.0 (0.1)	0.1 (0.2)	0.4 (0.5)
A_6	0.1 (0.1)	0.0 (0.0)	0.0 (0.1)	2.1 (0.9)	0.2 (0.2)	0.0 (0.1)	0.7 (0.4)	0.3 (0.3)	0.1 (0.1)	1.3 (0.8)	0.6 (0.5)	0.0 (0.1)		3.7 (2.1)	0.4 (0.3)	4.1 (1.4)	0.8 (0.5)	0.2 (0.3)
A_5	0.0 (0.0)	0.0 (0.1)	0.0 (0.0)	0.2 (0.2)	1.3 (0.5)	0.2 (0.2)	0.1 (0.2)	0.4 (0.3)	0.2 (0.2)	0.2 (0.2)	1.0 (0.7)	0.3 (0.3)	4.6 (2.3)		4.6 (2.4)	1.0 (0.7)	1.6 (1.0)	1.1 (0.6)
A_4	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.1)	0.2 (0.2)	2.0 (0.8)	0.0 (0.1)	0.2 (0.2)	0.7 (0.4)	0.0 (0.1)	0.6 (0.4)	1.3 (0.7)	0.3 (0.3)	3.8 (2.1)		0.2 (0.2)	0.7 (0.5)	3.8 (1.4)
A_3	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.3)	0.0 (0.1)	0.0 (0.1)	3.3 (1.4)	2.0 (1.0)	0.1 (0.2)	0.0 (0.1)	0.0 (0.0)	0.0 (0.0)	3.2 (1.7)	0.6 (0.5)	0.1 (0.2)		5.5 (2.3)	0.5 (0.5)
A_2	0.0 (0.1)	0.2 (0.3)	0.0 (0.1)	0.1 (0.2)	0.6 (0.5)	0.0 (0.1)	0.3 (0.3)	6.6 (2.0)	0.4 (0.4)	0.0 (0.1)	0.1 (0.2)	0.0 (0.1)	0.6 (0.5)	1.6 (1.0)	0.5 (0.5)	3.3 (1.6)		3.1 (1.6)
A_1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.2 (0.3)	0.0 (0.1)	1.9 (1.0)	3.5 (1.5)	0.0 (0.0)	0.0 (0.1)	0.1 (0.1)	0.1 (0.2)	0.5 (0.5)	3.3 (1.7)	0.5 (0.4)	5.4 (2.2)	

2. Method
2.3 Estimation of factors using log-liner model

For goals

$$\log(N_{iH_G}/T_i) = \lambda^i + \lambda^i{}_h + \lambda^i{}_{off}(X) + \lambda^i{}_{def}(Y) + \lambda^i{}_h * \lambda^i{}_{off}(X) + \lambda^i{}_h * \lambda^i{}_{def}(Y) + \lambda^i{}_{off}(X) * \lambda^i{}_{def}(Y) + \lambda^i{}_h * \lambda^i{}_{off}(X) * \lambda^i{}_{def}(Y)$$

$$\log(N_{i'A_G}/T_{i'}) = \lambda^i + \lambda^i{}_{off}(Y) + \lambda^i{}_{def}(X) + \lambda^{i'}{}_{off}(Y) * \lambda^i{}_{def}(X)$$

λ^i: Intercept for scoring goals from state i;

$\lambda^i{}_h$:Home-team advantage for scoring goals from state i;

$\lambda^i{}_{off}$ (X): Offensive strength of team X for scoring goals from state i;

$\lambda^i{}_{def}$ (X): Defensive strength of team X against conceding goals from state i;

2. Method
2.3 Estimation of factors using log-liner model

For goals

$$\log(N_{iH_G}/T_i) = \lambda^i + \lambda^i{}_h + \lambda^i{}_{off}(X) + \lambda^i{}_{def}(Y) + \lambda^i{}_h * \lambda^i{}_{off}(X) + \lambda^i{}_h * \lambda^i{}_{def}(Y) + \lambda^i{}_{off}(X) * \lambda^i{}_{def}(Y) + \lambda^i{}_h * \lambda^i{}_{off}(X) * \lambda^i{}_{def}(Y)$$

$$\log(N_{i'A_G}/T_{i'}) = \lambda^i + \lambda^i{}_{off}(Y) + \lambda^i{}_{def}(X) + \lambda^{i'}{}_{off}(Y) * \lambda^i{}_{def}(X)$$

λ^i: Intercept for scoring goals from state i;

$\lambda^i{}_h$:Home-team advantage for scoring goals from state i;

$\lambda^i{}_{off}$ (X): Offensive strength of team X for scoring goals from state i;

$\lambda^i{}_{def}$ (X): Defensive strength of team X against conceding goals from state i;

2. Method

2.3 Estimation of factors using log-liner model

For goals ($i=H_p^2$)

$$\log(N_{H_P^2 H_G}/T_{H_P^2}) = \lambda^{H_P^2} + \lambda^{H_P^2}{}_h + \lambda^{H_P^2}{}_{off}(X) + \lambda^{H_P^2}{}_{def}(Y)$$
$$+ \lambda^{H_P^2}{}_h * \lambda^{H_P^2}{}_{off}(X) + \lambda^{H_P^2}{}_h * \lambda^{H_P^2}{}_{def}(Y) + \lambda^{H_P^2}{}_{off}(X) * \lambda^{H_P^2}{}_{def}(Y)$$
$$+ \lambda^{H_P^2}{}_h * \lambda^{H_P^2}{}_{off}(X) * \lambda^{H_P^2}{}_{def}(Y)$$

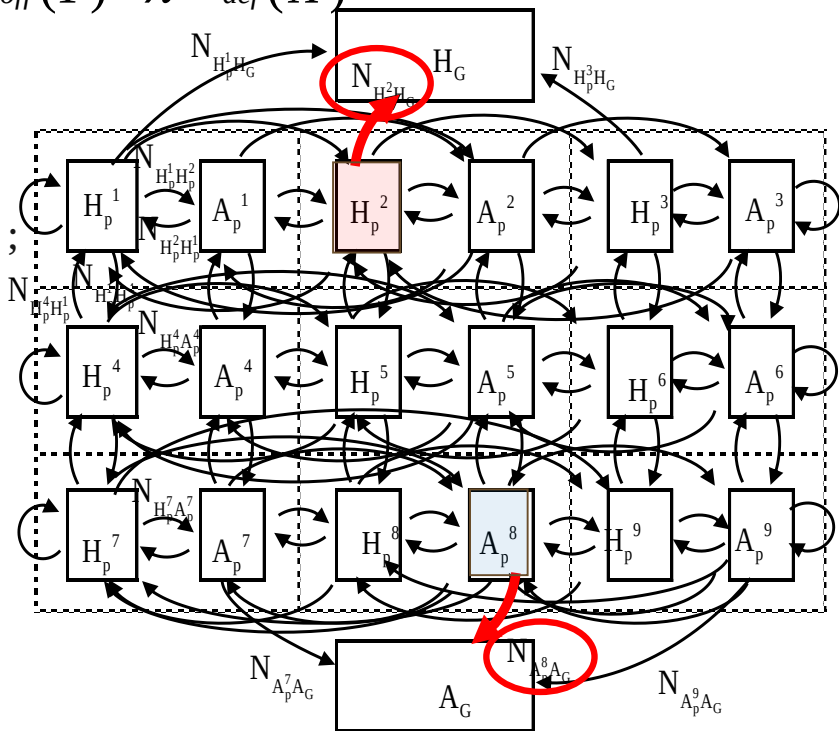
$$\log(N_{A_P^8 A_G}/T_{A_P^8}) = \lambda^{H_P^2} + \lambda^{H_P^2}{}_{off}(Y) + \lambda^{H_P^2}{}_{def}(X) + \lambda^{H_P^2}{}_{off}(Y) * \lambda^{H_P^2}{}_{def}(X)$$

$\lambda^{H_p^2}$: Intercept for scoring goals from state H_p^2 ;

$\lambda^{H_p^2}{}_h$:Home-team advantage for scoring goals from state H_p^2 ;

$\lambda^{H_p^2}{}_{off}$ (X): Offensive strength of team X for scoring goals from state H_p^2 ;

$\lambda^{H_p^2}{}_{def}$ (X): Defensive strength of team X against conceding goals from state H_p^2;



2. Method
2.3 Estimation of factors using log-liner model

For possession

$$\log(N_{ij}/T_i) = \mu^{ij} + \mu^{ij}_{h} + \mu^{ij}_{off}(X) + \mu^{ij}_{def}(Y) + \mu^{ij}_{h} * \mu^{ij}_{off}(X) + \mu^{ij}_{h} * \mu^{ij}_{def}(Y) + \mu^{ij}_{off}(X) * \mu^{ij}_{def}(Y) + \mu^{ij}_{h} * \mu^{ij}_{off}(X) * \mu^{ij}_{def}(Y)$$

$$\log(N_{i'j'}/T_{I'}) = \mu^{ij} + \mu^{ij}_{off}(Y) + \mu^{ij}_{def}(X) + \mu^{ij}_{off}(Y) * \mu^{ij}_{def}(X)$$

μ^{ij}: Intercept for propensity of changing state from i to j;
μ^{ij}_{h}: Home-team advantage for propensity of changing state from i to j;
μ^{ij}_{off} (X): Offensive strength of team X for propensity of changing state from i to j;
μ^{ij}_{def} (X), Defensive strength of team X against for propensity of changing state from i to j;

2. Method

2.3 Estimation of factors using log-liner model

For possession ($i=H_p^1$, $j=H_p^2$)

$$\log(N_{H_P^1H_P^2}/T_{H_P^1}) = \mu^{H_P^1H_P^2} + \mu^{H_P^1H_P^2}{}_h + \mu^{H_P^1H_P^2}{}_{off}(X) + \mu^{H_P^1H_P^2}{}_{def}(Y)$$
$$+ \mu^{H_P^1H_P^2}{}_h * \mu^{H_P^1H_P^2}{}_{off}(X) + \mu^{H_P^1H_P^2}{}_h * \mu^{H_P^1H_P^2}{}_{def}(Y) + \mu^{H_P^1H_P^2}{}_{off}(X) * \mu^{H_P^1H_P^2}{}_{def}(Y)$$
$$+ \mu^{H_P^1H_P^2}{}_h * \mu^{H_P^1H_P^2}{}_{off}(X) * \mu^{H_P^1H_P^2}{}_{def}(Y)$$

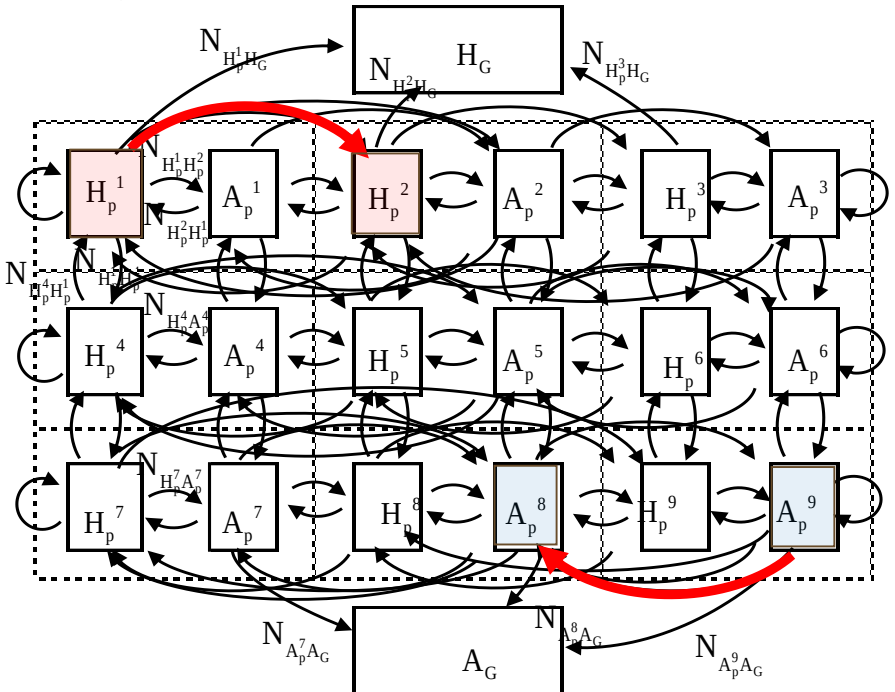
$$\log(N_{A_P^9A_P^8}/T_{A_P^9}) = \mu^{H_P^1H_P^2} + \mu^{H_P^1H_P^2}{}_{off}(Y) + \mu^{H_P^1H_P^2}{}_{def}(X) + \mu^{H_P^1H_P^2}{}_{off}(Y) * \mu^{H_P^1H_P^2}{}_{def}(X)$$

$\mu^{H_p^1H_p^2}$: Intercept for propensity of changing state from H_p^1 to H_p^2;

$\mu^{H_p^1H_p^2}{}_h$: Home-team advantage for propensity of changing state from H_p^1 to H_p^2;

$\mu^{H_p^1H_p^2}{}_{off}(X)$: Offensive strength of team X for propensity of changing state from H_p^1 to H_p^2;

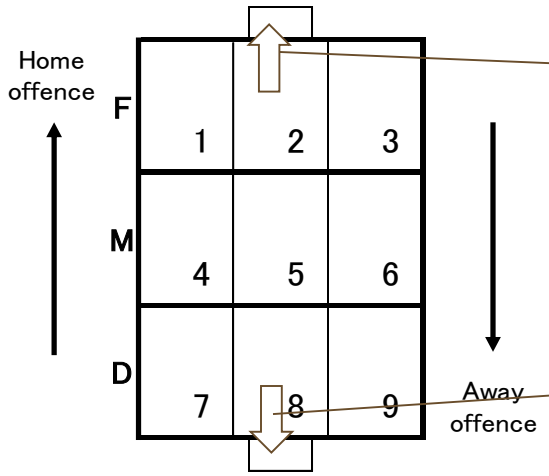
$\mu^{H_p^1H_p^2}{}_{def}(X)$: Defensive strength of team X against for propensity of changing state from H_p^1 to H_p^2;



3. Result
3.3 20-state model

Data

No.	Home	Away	Goal						Transition										Time (min.)															
			N_{H1G}	N_{H2G}	N_{H3G}	N_{A9G}	N_{A8G}	N_{A7G}	N_{H1H2}	N_{H1A2}	N_{H3H2}	N_{H5H2}	N_{H5A5}		N_{A9A8}	N_{A8H8}	N_{A7A8}	N_{A5A8}	N_{A5H5}	T_{H1}	T_{H2}	T_{H3}	T_{H4}	T_{H5}	T_{H6}	T_{H7}	T_{H8}	T_{H9}	T_{A9}	T_{A8}	T_{A7}	T_{A6}	T_{A5}	T_{A4}	T_{A3}	T_{A2}	T_{A1}
1	V.Sendai	M.Yamagata		2		0			13	2	10	3	2		12	11	22	6	6	1.4	1.3	2.1	3.2	2.9	4.5	0.8	3.5	1.6	2.1	3.6	2.5	4.7	3.1	3.7	2.5	3.0	2.0
2	M.Yamagata	V.Sendai		1		0	1		13	2	6	5	3		12	14	10	5	6	3.0	2.1	1.8	4.3	2.1	2.7	1.5	2.7	1.7	2.0	2.5	1.8	4.0	2.1	3.1	1.3	3.7	2.0
3	S.Hiroshima	V.Sendai		2		0			12	4	17	3	3		7	15	11	8	3	2.9	1.9	2.8	3.4	3.4	6.0	2.6	4.8	2.0	1.9	1.5	3.7	4.5	6.7	6.4	1.1	3.5	1.2
4	V.Sendai	S.Hiroshima		3		0	3	1	22	2	19	8	2		7	8	9	5	4	4.2	3.5	3.5	6.6	6.9	4.8	1.5	2.6	1.0	1.8	1.4	1.7	4.3	3.3	2.8	3.3	4.0	2.1
5	S.Hiroshima	M.Yamagata		5		0	1		13	4	14	9	6		17	18	16	9	4	2.3	2.2	1.4	4.3	3.3	3.6	3.2	4.7	3.4	2.9	2.8	2.8	5.4	4.8	3.7	1.4	2.8	0.8
6	M.Yamagata	S.Hiroshima		1		0	2	1	19	4	11	10	2		9	13	14	3	5	2.5	2.0	2.6	4.1	5.9	6.0	1.7	2.8	1.2	1.6	1.6	2.3	4.0	4.1	4.8	3.3	6.7	2.0
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
305	A.Niigata	V.Kofu		0		0	2		16	5	11	12	3		10	32	6	6	2	3.3	4.1	1.7	6.4	6.4	4.9	2.0	2.3	1.4	2.1	1.6	2.7	2.8	3.6	4.6	2.0	4.7	1.9
306	S.Shimizu	V.Kofu		0		1	1		27	8	22	12	3		8	13	3	2	5	3.5	5.3	2.6	7.3	5.3	4.8	1.7	3.1	1.1	1.4	0.9	1.4	3.0	1.9	2.7	2.4	4.2	2.1



Number of goals in a game

	H_G			A_G		
H_p^1	0.05	±	0.22		–	
H_p^2	1.31	±	1.29		–	
H_p^3	0.04	±	0.19		–	
H_p^4	0.00	±	0.06		–	
H_p^5	0	±	0		–	
H_p^6	0.00	±	0.06		–	
A_p^4		–		0	±	0
A_p^5		–		0	±	0
A_p^6		–		0	±	0
A_p^7		–		0.059	±	0.26
A_p^8		–		1.196	±	1.08
A_p^9		–		0.02	±	0.14

Mean ± SD

3. Result

3.3 20-state model

Data

No.	Home	Away	Goal						Transition										Time (min.)															
			N_{H1G}	N_{H2G}	N_{H3G}	N_{A9G}	N_{A8G}	N_{A7G}	N_{H1H2}	N_{H1A2}	N_{H3H2}	N_{H5H2}	N_{H5A5}		N_{A9A8}	N_{A8H8}	N_{A7A8}	N_{A5A8}	N_{A5H5}	T_{H1}	T_{H2}	T_{H3}	T_{H4}	T_{H5}	T_{H6}	T_{H7}	T_{H8}	T_{H9}	T_{A9}	T_{A8}	T_{A7}	T_{A6}	T_{A5}	T_{A4}	T_{A3}	T_{A2}	T_{A1}
1	V.Sendai	M.Yamagata		2		0			13	2	10	3	2		12	11	22	6	6	1.4	1.3	2.1	3.2	2.9	4.5	0.8	3.5	1.6	2.1	3.6	2.5	4.7	3.1	3.7	2.5	3.0	2.0
2	M.Yamagata	V.Sendai		1		0	1		13	2	6	5	3		12	14	10	5	6	3.0	2.1	1.8	4.3	2.1	2.7	1.5	2.7	1.7	2.0	2.5	1.8	4.0	2.1	3.1	1.3	3.7	2.0
3	S.Hiroshima	V.Sendai		2		0			12	4	17	3	3		7	15	11	8	3	2.9	1.9	2.8	3.4	3.4	6.0	2.6	4.8	2.0	1.9	1.5	3.7	4.5	6.7	6.4	1.1	3.5	1.2
4	V.Sendai	S.Hiroshima		3		0	3	1	22	2	19	8	2		7	8	9	5	4	4.2	3.5	3.5	6.6	6.9	4.8	1.5	2.6	1.0	1.8	1.4	1.7	4.3	3.3	2.8	3.3	4.0	2.1
5	S.Hiroshima	M.Yamagata		5		0	1		13	4	14	9	6		17	18	16	9	4	2.3	2.2	1.4	4.3	3.3	3.6	3.2	4.7	3.4	2.9	2.8	2.8	5.4	4.8	3.7	1.4	2.8	0.8
6	M.Yamagata	S.Hiroshima		1		0	2	1	19	4	11	10	2		9	13	14	3	5	2.5	2.0	2.6	4.1	5.9	6.0	1.7	2.8	1.2	1.6	1.6	2.3	4.0	4.1	4.8	3.3	6.7	2.0
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
305	A.Niigata	V.Kofu		0		0	2		16	5	11	12	3		10	32	6	6	2	3.3	4.1	1.7	6.4	6.4	4.9	2.0	2.3	1.4	2.1	1.6	2.7	2.8	3.6	4.6	2.0	4.7	1.9
306	S.Shimizu	V.Kofu		0		1	1		27	8	22	12	3		8	13	3	2	5	3.5	5.3	2.6	7.3	5.3	4.8	1.7	3.1	1.1	1.4	0.9	1.4	3.0	1.9	2.7	2.4	4.2	2.1

Number of transitions between states in a game.

	Hp^1	Hp^2	Hp^3	Hp^4	Hp^5	Hp^6	Hp^7	Hp^8	Hp^9	Ap^1	Ap^2	Ap^3	Ap^4	Ap^5	Ap^6	Ap^7	Ap^8	Ap^9	Time
Hp^1		15.1 ± 6.2	1.3 ± 1.2	8.4 ± 4.1	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.4	0.0 ± 0.2	0.0 ± 0.1	8.5 ± 3.6	4.6 ± 2.3	0.2 ± 0.4	0.6 ± 0.8	0.1 ± 0.2	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	2.7 ± 1.0
Hp^2	8.6 ± 4.5		8.6 ± 4.4	1.6 ± 1.5	3.9 ± 2.5	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.3	0.1 ± 0.2	0.8 ± 1.0	17.6 ± 5.2	0.7 ± 0.8	0.3 ± 0.5	1.5 ± 1.3	0.1 ± 0.3	0.0 ± 0.2	0.3 ± 0.5	0.0 ± 0.1	2.6 ± 1.0
Hp^3	1.3 ± 1.2	14.3 ± 5.7		0.2 ± 0.5	1.3 ± 1.2	7.7 ± 4.3	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.1 ± 0.4	5.1 ± 2.6	7.9 ± 3.1	0.1 ± 0.3	0.1 ± 0.2	0.4 ± 0.6	0.0 ± 0.0	0.0 ± 0.1	0.0 ± 0.0	2.5 ± 0.8
Hp^4	19.1 ± 6.4	3.2 ± 2.1	1.1 ± 1.1		18.0 ± 9.9	1.8 ± 1.8	5.6 ± 3.1	3.0 ± 2.0	0.2 ± 0.4	2.9 ± 1.9	1.3 ± 1.1	0.2 ± 0.4	8.6 ± 3.6	0.8 ± 0.9	0.1 ± 0.4	0.3 ± 0.6	0.0 ± 0.1	0.0 ± 0.2	4.7 ± 1.6
Hp^5	5.1 ± 2.7	6.6 ± 4.1	4.3 ± 2.4	20.2 ± 10.0		18.6 ± 9.3	1.0 ± 1.1	4.0 ± 2.7	1.1 ± 1.1	0.6 ± 0.8	1.6 ± 1.3	0.6 ± 0.8	0.7 ± 0.9	4.7 ± 2.4	0.6 ± 0.7	0.0 ± 0.1	0.0 ± 0.2	0.0 ± 0.1	4.1 ± 1.6
Hp^6	1.1 ± 1.3	3.4 ± 2.0	17.8 ± 6.0	1.7 ± 1.6	16.7 ± 9.0		0.1 ± 0.4	2.7 ± 2.2	5.7 ± 3.8	0.2 ± 0.5	1.3 ± 1.2	3.0 ± 1.9	0.1 ± 0.3	1.0 ± 1.0	8.3 ± 4.0	0.0 ± 0.2	0.0 ± 0.2	0.3 ± 0.6	4.4 ± 1.5
Hp^7	0.9 ± 1.1	0.2 ± 0.4	0.1 ± 0.3	12.1 ± 4.4	2.4 ± 1.7	0.2 ± 0.5		7.5 ± 4.5	0.5 ± 0.8	0.4 ± 0.6	0.1 ± 0.4	0.0 ± 0.2	1.9 ± 1.4	0.5 ± 0.7	0.0 ± 0.2	2.5 ± 1.9	0.1 ± 0.3	0.0 ± 0.1	1.9 ± 0.6
Hp^8	1.1 ± 1.3	1.0 ± 1.3	1.0 ± 1.3	7.7 ± 3.3	11.9 ± 4.9	8.0 ± 3.6	8.7 ± 4.8		8.6 ± 4.6	0.4 ± 0.7	0.6 ± 0.9	0.4 ± 0.6	1.1 ± 1.1	1.7 ± 1.4	1.1 ± 1.1	0.2 ± 0.5	0.8 ± 0.9	0.2 ± 0.4	3.5 ± 0.9
Hp^9	0.1 ± 0.3	0.4 ± 0.7	0.9 ± 1.2	0.3 ± 0.5	2.5 ± 1.8	12.0 ± 5.0	0.6 ± 0.9	7.4 ± 4.7		0.0 ± 0.2	0.3 ± 0.6	0.5 ± 0.7	0.1 ± 0.2	0.5 ± 0.7	1.9 ± 1.5	0.0 ± 0.1	0.1 ± 0.3	2.5 ± 1.8	1.8 ± 0.6
Ap^1	2.7 ± 2.0	0.1 ± 0.3	0.0 ± 0.1	2.2 ± 1.7	0.6 ± 0.9	0.1 ± 0.2	0.6 ± 0.8	0.3 ± 0.5	0.1 ± 0.2		6.8 ± 4.2	0.5 ± 0.8	11.6 ± 4.4	2.2 ± 1.5	0.3 ± 0.5	1.1 ± 1.2	0.4 ± 0.7	0.1 ± 0.3	1.8 ± 0.6
Ap^2	0.2 ± 0.5	1.1 ± 1.2	0.3 ± 0.5	1.2 ± 1.3	1.8 ± 1.3	1.3 ± 1.3	0.5 ± 0.7	0.6 ± 0.9	0.4 ± 0.7	8.6 ± 4.1		9.3 ± 4.8	8.1 ± 3.6	11.7 ± 4.9	8.2 ± 3.8	1.0 ± 1.3	1.0 ± 1.3	1.1 ± 1.4	3.6 ± 0.9
Ap^3	0.0 ± 0.0	0.1 ± 0.4	2.8 ± 1.9	0.1 ± 0.3	0.5 ± 0.8	2.1 ± 1.5	0.0 ± 0.1	0.2 ± 0.4	0.4 ± 0.7	0.5 ± 0.8	7.1 ± 4.1		0.3 ± 0.6	2.4 ± 1.6	12.5 ± 4.7	0.0 ± 0.2	0.2 ± 0.4	0.7 ± 0.9	1.9 ± 0.6
Ap^4	0.3 ± 0.6	0.0 ± 0.1	0.1 ± 0.3	8.9 ± 3.6	0.9 ± 1.1	0.1 ± 0.3	3.1 ± 1.9	1.3 ± 1.2	0.2 ± 0.5	5.4 ± 3.2	2.7 ± 2.1	0.1 ± 0.4		15.8 ± 9.0	1.5 ± 1.5	17.4 ± 6.1	3.4 ± 2.1	1.0 ± 1.2	4.3 ± 1.4
Ap^5	0.0 ± 0.1	0.1 ± 0.3	0.0 ± 0.2	0.7 ± 0.9	5.1 ± 2.2	0.7 ± 0.9	0.6 ± 0.8	1.5 ± 1.3	0.6 ± 0.8	0.9 ± 0.9	4.1 ± 2.6	1.0 ± 1.1	18.3 ± 9.3		18.3 ± 9.5	4.2 ± 2.6	6.4 ± 3.8	4.3 ± 2.5	4.0 ± 1.9
Ap^6	0.0 ± 0.2	0.0 ± 0.1	0.3 ± 0.6	0.2 ± 0.4	0.9 ± 1.0	8.7 ± 3.6	0.2 ± 0.4	1.1 ± 1.1	3.0 ± 1.9	0.1 ± 0.3	2.6 ± 1.9	5.7 ± 3.0	1.5 ± 1.5	16.8 ± 9.3		1.0 ± 1.1	3.0 ± 2.0	17.0 ± 6.3	4.5 ± 1.4
Ap^7	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.1	0.5 ± 0.7	0.1 ± 0.2	0.0 ± 0.2	7.8 ± 3.2	4.7 ± 2.2	0.2 ± 0.4	0.1 ± 0.3	0.0 ± 0.1	0.0 ± 0.1	7.6 ± 3.9	1.3 ± 1.3	0.1 ± 0.4		13.0 ± 5.5	1.3 ± 1.3	2.4 ± 0.9
Ap^8	0.0 ± 0.2	0.4 ± 0.6	0.0 ± 0.2	0.2 ± 0.5	1.3 ± 1.1	0.1 ± 0.3	0.6 ± 0.8	15.7 ± 4.8	0.9 ± 1.0	0.1 ± 0.3	0.1 ± 0.4	0.1 ± 0.2	1.5 ± 1.3	3.8 ± 2.5	1.3 ± 1.2	7.8 ± 3.9		7.4 ± 3.7	2.4 ± 0.9
Ap^9	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.2	0.5 ± 0.7	0.1 ± 0.3	4.4 ± 2.2	8.0 ± 3.4	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.2 ± 0.4	1.2 ± 1.1	7.5 ± 3.8	1.1 ± 1.0	12.5 ± 5.0		2.3 ± 0.9

3. Result

3.3 20-state model

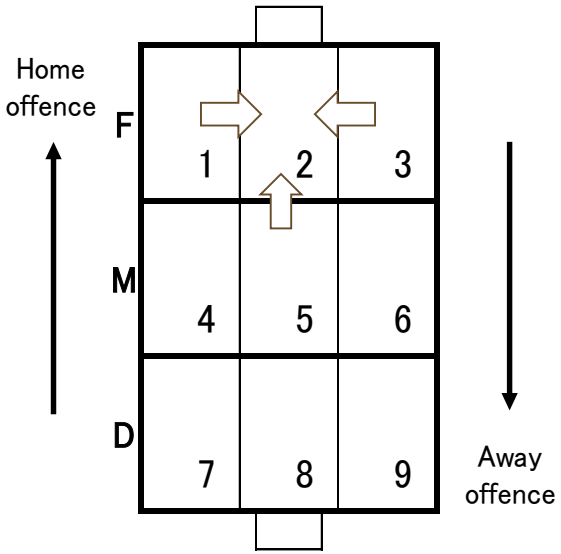
Number of transitions between states in a game

	Hp^1	Hp^2	Hp^3	Hp^4	Hp^5	Hp^6	Hp^7	Hp^8	Hp^9	Ap^1	Ap^2	Ap^3	Ap^4	Ap^5	Ap^6	Ap^7	Ap^8	Ap^9	Time
Hp^1		15.1 ± 6.2	1.3 ± 1.2	8.4 ± 4.1	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.4	0.0 ± 0.2	0.0 ± 0.1	8.5 ± 3.6	4.6 ± 2.3	0.2 ± 0.4	0.6 ± 0.8	0.1 ± 0.2	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	2.7 ± 1.0
Hp^2	8.6 ± 4.5		8.6 ± 4.4	1.6 ± 1.5	3.9 ± 2.5	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.3	0.1 ± 0.2	0.8 ± 1.0	17.6 ± 5.2	0.7 ± 0.8	0.3 ± 0.5	1.5 ± 1.3	0.1 ± 0.3	0.0 ± 0.2	0.3 ± 0.5	0.0 ± 0.1	2.6 ± 1.0
Hp^3	1.3 ± 1.2	14.3 ± 5.7		0.2 ± 0.5	1.3 ± 1.2	7.7 ± 4.3	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.1 ± 0.4	5.1 ± 2.6	7.9 ± 3.1	0.1 ± 0.3	0.1 ± 0.2	0.4 ± 0.6	0.0 ± 0.0	0.0 ± 0.1	0.0 ± 0.0	2.5 ± 0.8
Hp^4	19.1 ± 6.4	3.2 ± 2.1	1.1 ± 1.1		18.0 ± 9.9	1.8 ± 1.8	5.6 ± 3.1	3.0 ± 2.0	0.2 ± 0.4	2.9 ± 1.9	1.3 ± 1.1	0.2 ± 0.4	8.6 ± 3.6	0.8 ± 0.9	0.1 ± 0.4	0.3 ± 0.6	0.0 ± 0.1	0.0 ± 0.2	4.7 ± 1.6
Hp^5	5.1 ± 2.7	6.6 ± 4.1	4.3 ± 2.4	20.2 ± 10.0		18.6 ± 9.3	1.0 ± 1.1	4.0 ± 2.7	1.1 ± 1.1	0.6 ± 0.8	1.6 ± 1.3	0.6 ± 0.8	0.7 ± 0.9	4.7 ± 2.4	0.6 ± 0.7	0.0 ± 0.1	0.0 ± 0.2	0.0 ± 0.1	4.1 ± 1.6
Hp^6	1.1 ± 1.3	3.4 ± 2.0	17.8 ± 6.0	1.7 ± 1.6	16.7 ± 9.0		0.1 ± 0.4	2.7 ± 2.2	5.7 ± 3.8	0.2 ± 0.5	1.3 ± 1.2	3.0 ± 1.9	0.1 ± 0.3	1.0 ± 1.0	8.3 ± 4.0	0.0 ± 0.2	0.0 ± 0.2	0.3 ± 0.6	4.4 ± 1.5
Hp^7	0.9 ± 1.1	0.2 ± 0.4	0.1 ± 0.3	12.1 ± 4.4	2.4 ± 1.7	0.2 ± 0.5		7.5 ± 4.5	0.5 ± 0.8	0.4 ± 0.6	0.1 ± 0.4	0.0 ± 0.2	1.9 ± 1.4	0.5 ± 0.7	0.0 ± 0.2	2.5 ± 1.9	0.1 ± 0.3	0.0 ± 0.1	1.9 ± 0.6
Hp^8	1.1 ± 1.3	1.0 ± 1.3	1.0 ± 1.3	7.7 ± 3.3	11.9 ± 4.9	8.0 ± 3.6	8.7 ± 4.8		8.6 ± 4.6	0.4 ± 0.7	0.6 ± 0.9	0.4 ± 0.6	1.1 ± 1.1	1.7 ± 1.4	1.1 ± 1.1	0.2 ± 0.5	0.8 ± 0.9	0.2 ± 0.4	3.5 ± 0.9
Hp^9	0.1 ± 0.3	0.4 ± 0.7	0.9 ± 1.2	0.3 ± 0.5	2.5 ± 1.8	12.0 ± 5.0	0.6 ± 0.9	7.4 ± 4.7		0.0 ± 0.2	0.3 ± 0.6	0.5 ± 0.7	0.1 ± 0.2	0.5 ± 0.7	1.9 ± 1.5	0.0 ± 0.1	0.1 ± 0.3	2.5 ± 1.8	1.8 ± 0.6
Ap^1	2.7 ± 2.0	0.1 ± 0.3	0.0 ± 0.1	2.2 ± 1.7	0.6 ± 0.9	0.1 ± 0.2	0.6 ± 0.8	0.3 ± 0.5	0.1 ± 0.2		6.8 ± 4.2	0.5 ± 0.8	11.6 ± 4.4	2.2 ± 1.5	0.3 ± 0.5	1.1 ± 1.2	0.4 ± 0.7	0.1 ± 0.3	1.8 ± 0.6
Ap^2	0.2 ± 0.5	1.1 ± 1.2	0.3 ± 0.5	1.2 ± 1.3	1.8 ± 1.3	1.3 ± 1.3	0.5 ± 0.7	0.6 ± 0.9	0.4 ± 0.7	8.6 ± 4.1		9.3 ± 4.8	8.1 ± 3.6	11.7 ± 4.9	8.2 ± 3.8	1.0 ± 1.3	1.0 ± 1.3	1.1 ± 1.4	3.6 ± 0.9
Ap^3	0.0 ± 0.0	0.1 ± 0.4	2.8 ± 1.9	0.1 ± 0.3	0.5 ± 0.8	2.1 ± 1.5	0.0 ± 0.1	0.2 ± 0.4	0.4 ± 0.7	0.5 ± 0.8	7.1 ± 4.1		0.3 ± 0.6	2.4 ± 1.6	12.5 ± 4.7	0.0 ± 0.2	0.2 ± 0.4	0.7 ± 0.9	1.9 ± 0.6
Ap^4	0.3 ± 0.6	0.0 ± 0.1	0.1 ± 0.3	8.9 ± 3.6	0.9 ± 1.1	0.1 ± 0.3	3.1 ± 1.9	1.3 ± 1.2	0.2 ± 0.5	5.4 ± 3.2	2.7 ± 2.1	0.1 ± 0.4		15.8 ± 9.0	1.5 ± 1.5	17.4 ± 6.1	3.4 ± 2.1	1.0 ± 1.2	4.3 ± 1.4
Ap^5	0.0 ± 0.1	0.1 ± 0.3	0.0 ± 0.2	0.7 ± 0.9	5.1 ± 2.2	0.7 ± 0.9	0.6 ± 0.8	1.5 ± 1.3	0.6 ± 0.8	0.9 ± 0.9	4.1 ± 2.6	1.0 ± 1.1	18.3 ± 9.3		18.3 ± 9.5	4.2 ± 2.6	6.4 ± 3.8	4.3 ± 2.5	4.0 ± 1.9
Ap^6	0.0 ± 0.2	0.0 ± 0.1	0.3 ± 0.6	0.2 ± 0.4	0.9 ± 1.0	8.7 ± 3.6	0.2 ± 0.4	1.1 ± 1.1	3.0 ± 1.9	0.1 ± 0.3	2.6 ± 1.9	5.7 ± 3.0	1.5 ± 1.5	16.8 ± 9.3		1.0 ± 1.1	3.0 ± 2.0	17.0 ± 6.3	4.5 ± 1.4
Ap^7	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.1	0.5 ± 0.7	0.1 ± 0.2	0.0 ± 0.2	7.8 ± 3.2	4.7 ± 2.2	0.2 ± 0.4	0.1 ± 0.3	0.0 ± 0.1	0.0 ± 0.1	7.6 ± 3.9	1.3 ± 1.3	0.1 ± 0.4		13.0 ± 5.5	1.3 ± 1.3	2.4 ± 0.9
Ap^8	0.0 ± 0.2	0.4 ± 0.6	0.0 ± 0.2	0.2 ± 0.5	1.3 ± 1.1	0.1 ± 0.3	0.6 ± 0.8	15.7 ± 4.8	0.9 ± 1.0	0.1 ± 0.3	0.1 ± 0.4	0.1 ± 0.2	1.5 ± 1.3	3.8 ± 2.5	1.3 ± 1.2	7.8 ± 3.9		7.4 ± 3.7	2.4 ± 0.9
Ap^9	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.2	0.5 ± 0.7	0.1 ± 0.3	4.4 ± 2.2	8.0 ± 3.4	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.2 ± 0.4	1.2 ± 1.1	7.5 ± 3.8	1.1 ± 1.0	12.5 ± 5.0		2.3 ± 0.9

3. Result
3.3 20-state model

Selection of Log-Linear Models

Transition	Model achieving Min. AIC	Degrees of Freedom	Number of Parameters	logL*	Deviance −2logL*	Residual Deviance	AIC (Minimum)
$H_p^2 \rightarrow H_G$	1+H+Off+Def	611	576	−945.7	1891.4	862.6	1963.4
$H_p^1 \rightarrow H_p^2$	1+H+Off+Def	611	576	−1687.3	3374.6	688.0	3446.6
$H_p^2 \rightarrow A_p^2$	1+H+Off+Def	611	576	−1816.9	3633.9	810.6	3705.9
$H_p^5 \rightarrow A_p^5$	1+H+Off+Def+H*Off+H*Def	611	542	−1454.7	2909.3	871.2	3049.3
$H_p^5 \rightarrow H_p^2$	1+H+Off+Def	611	576	−1531.1	3062.2	890.6	3134.2
$H_p^3 \rightarrow H_p^2$	1+H+Off+Def	611	576	−1666.4	3332.744	655.1	3404.7



JUNTENDO

3. Result
3.3 20-state model

Selection of Log-Linear Models

For goals

	H_G		A_G		
H_p^1	0.05	±	0.22	–	
H_p^2	1.31	±	1.29	–	
H_p^3	0.04	±	0.19	–	
H_p^4	0.00	±	0.06	–	
H_p^5	0	±	0	–	
H_p^6	0.00	±	0.06	–	
A_p^4	–		0	±	0
A_p^5	–		0	±	0
A_p^6	–		0	±	0
A_p^7	–		0.059	±	0.26
A_p^8	–		1.196	±	1.08
A_p^9	–		0.02	±	0.14

	H_G	A_G
H_p^1	1+H	—
H_p^2	1+H+Off+Def	—
H_p^3	1	—
H_p^4	1+H	—
H_p^5		—
H_p^6	1	—
A_p^4	—	1
A_p^5	—	
A_p^6	—	1
A_p^7	—	1
A_p^8	—	1+Off+Def
A_p^9	—	1

For possession

	Hp^1	Hp^2	Hp^3	Hp^4	Hp^5	Hp^6	Hp^7	Hp^8	Hp^9	Ap^1	Ap^2	Ap^3	Ap^4	Ap^5	Ap^6	Ap^7	Ap^8	Ap^9	Time
Hp^1		15.1 ± 6.2	1.3 ± 1.2	8.4 ± 4.1	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.4	0.0 ± 0.2	0.0 ± 0.1	8.5 ± 3.6	4.6 ± 2.3	0.2 ± 0.4	0.6 ± 0.8	0.1 ± 0.2	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	2.7 ± 1.0
Hp^2	8.6 ± 4.5		8.6 ± 4.4	1.6 ± 1.5	3.9 ± 2.5	1.5 ± 1.4	0.1 ± 0.4	0.1 ± 0.3	0.1 ± 0.2	0.8 ± 1.0	17.6 ± 5.2	0.7 ± 0.8	0.3 ± 0.5	1.5 ± 1.3	0.1 ± 0.3	0.0 ± 0.2	0.3 ± 0.5	0.0 ± 0.1	2.6 ± 1.0
Hp^3	1.3 ± 1.2	14.3 ± 5.7		0.2 ± 0.5	1.3 ± 1.2	7.7 ± 4.3	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.1 ± 0.4	5.1 ± 2.6	7.9 ± 3.1	0.1 ± 0.3	0.1 ± 0.2	0.4 ± 0.6	0.0 ± 0.0	0.0 ± 0.1	0.0 ± 0.0	2.5 ± 0.8
Hp^4	19.1 ± 6.4	3.2 ± 2.1	1.1 ± 1.1	18.0 ± 9.9	1.8 ± 1.8	5.6 ± 3.1	3.0 ± 2.0	0.2 ± 0.4	2.9 ± 1.9	1.3 ± 1.1	0.2 ± 0.4	8.6 ± 3.6	0.8 ± 0.9	0.1 ± 0.4	0.3 ± 0.6	0.0 ± 0.1	0.0 ± 0.2	4.7 ± 1.6
Hp^5	5.1 ± 2.7	6.6 ± 4.1	4.3 ± 2.4	20.2 ± 10.0		18.6 ± 9.3	1.0 ± 1.1	4.0 ± 2.7	1.1 ± 1.1	0.6 ± 0.8	1.6 ± 1.3	0.6 ± 0.8	0.7 ± 0.9	4.7 ± 2.4	0.6 ± 0.7	0.0 ± 0.1	0.0 ± 0.2	0.0 ± 0.1	4.1 ± 1.6
Hp^6	1.1 ± 1.3	3.4 ± 2.0	17.8 ± 6.0	1.7 ± 1.6	16.7 ± 9.0		0.1 ± 0.4	2.7 ± 2.2	5.7 ± 3.8	0.2 ± 0.5	1.3 ± 1.2	3.0 ± 1.9	0.1 ± 0.3	1.0 ± 1.0	8.3 ± 4.0	0.0 ± 0.2	0.0 ± 0.2	0.3 ± 0.6	4.4 ± 1.5
Hp^7	0.9 ± 1.1	0.2 ± 0.4	0.1 ± 0.3	12.1 ± 4.4	2.4 ± 1.7	0.2 ± 0.5		7.5 ± 4.5	0.5 ± 0.8	0.4 ± 0.6	0.1 ± 0.4	0.0 ± 0.2	1.9 ± 1.4	0.5 ± 0.7	0.0 ± 0.2	2.5 ± 1.9	0.1 ± 0.3	0.0 ± 0.1	1.9 ± 0.6
Hp^8	1.1 ± 1.3	1.0 ± 1.3	1.0 ± 1.3	7.7 ± 3.3	11.9 ± 4.9	8.0 ± 3.6	8.7 ± 4.8		8.6 ± 4.6	0.4 ± 0.7	0.6 ± 0.9	0.4 ± 0.6	1.1 ± 1.1	1.7 ± 1.4	1.1 ± 1.1	0.2 ± 0.5	0.8 ± 0.9	0.2 ± 0.4	3.5 ± 0.9
Hp^9	0.1 ± 0.3	0.4 ± 0.7	0.9 ± 1.2	0.3 ± 0.5	2.5 ± 1.8	12.0 ± 5.0	0.6 ± 0.9	7.4 ± 4.7		0.0 ± 0.2	0.3 ± 0.6	0.5 ± 0.7	0.1 ± 0.2	0.5 ± 0.7	1.9 ± 1.5	0.0 ± 0.1	0.1 ± 0.3	2.5 ± 1.8	1.8 ± 0.6
Ap^1	2.7 ± 2.0	0.1 ± 0.3	0.0 ± 0.1	2.2 ± 1.7	0.6 ± 0.9	0.1 ± 0.2	0.6 ± 0.8	0.3 ± 0.5	0.1 ± 0.2		6.8 ± 4.2	0.5 ± 0.8	11.6 ± 4.4	2.2 ± 1.5	0.3 ± 0.5	1.1 ± 1.2	0.4 ± 0.7	0.1 ± 0.3	1.8 ± 0.6
Ap^2	0.2 ± 0.5	1.1 ± 1.2	0.3 ± 0.5	1.2 ± 1.3	1.8 ± 1.3	1.3 ± 1.3	0.5 ± 0.7	0.6 ± 0.9	0.4 ± 0.7	8.6 ± 4.1		9.3 ± 4.8	8.1 ± 3.6	11.7 ± 4.9	8.2 ± 3.8	1.0 ± 1.3	1.0 ± 1.3	1.1 ± 1.4	3.6 ± 0.9
Ap^3	0.0 ± 0.0	0.1 ± 0.4	2.8 ± 1.9	0.1 ± 0.3	0.5 ± 0.8	2.1 ± 1.5	0.0 ± 0.1	0.2 ± 0.4	0.4 ± 0.7	0.5 ± 0.8	7.1 ± 4.1		0.3 ± 0.6	2.4 ± 1.6	12.5 ± 4.7	0.0 ± 0.2	0.2 ± 0.4	0.7 ± 0.9	1.9 ± 0.6
Ap^4	0.3 ± 0.6	0.0 ± 0.1	0.1 ± 0.3	8.9 ± 3.6	0.9 ± 1.1	0.1 ± 0.3	3.1 ± 1.9	1.3 ± 1.2	0.2 ± 0.5	5.4 ± 3.2	2.7 ± 2.1	0.1 ± 0.4		15.8 ± 9.0	1.5 ± 1.5	17.4 ± 6.1	3.4 ± 2.1	1.0 ± 1.2	4.3 ± 1.4
Ap^5	0.0 ± 0.1	0.1 ± 0.3	0.0 ± 0.2	0.7 ± 0.9	5.1 ± 2.2	0.7 ± 0.9	0.6 ± 0.8	1.5 ± 1.3	0.6 ± 0.8	0.9 ± 0.9	4.1 ± 2.6	1.0 ± 1.1	18.3 ± 9.3		18.3 ± 9.5	4.2 ± 2.6	6.4 ± 3.8	4.3 ± 2.5	4.0 ± 1.9
Ap^6	0.0 ± 0.2	0.0 ± 0.1	0.3 ± 0.6	0.2 ± 0.4	0.9 ± 1.0	8.7 ± 3.6	0.2 ± 0.4	1.1 ± 1.1	3.0 ± 1.9	0.1 ± 0.3	2.6 ± 1.9	5.7 ± 3.0	1.5 ± 1.5	16.8 ± 9.3		1.0 ± 1.1	3.0 ± 2.0	17.0 ± 6.3	4.5 ± 1.4
Ap^7	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.1	0.5 ± 0.7	0.1 ± 0.2	0.0 ± 0.2	7.8 ± 3.2	4.7 ± 2.2	0.2 ± 0.4	0.1 ± 0.3	0.0 ± 0.1	0.0 ± 0.1	7.6 ± 3.9	1.3 ± 1.3	0.1 ± 0.4		13.0 ± 5.5	1.3 ± 1.3	2.4 ± 0.9
Ap^8	0.0 ± 0.2	0.4 ± 0.6	0.0 ± 0.2	0.2 ± 0.5	1.3 ± 1.1	0.1 ± 0.3	0.6 ± 0.8	15.7 ± 4.8	0.9 ± 1.0	0.1 ± 0.3	0.1 ± 0.4	0.1 ± 0.2	1.5 ± 1.3	3.8 ± 2.5	1.3 ± 1.2	7.8 ± 3.9		7.4 ± 3.7	2.4 ± 0.9
Ap^9	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	0.0 ± 0.2	0.5 ± 0.7	0.1 ± 0.3	4.4 ± 2.2	8.0 ± 3.4	0.0 ± 0.1	0.0 ± 0.2	0.1 ± 0.3	0.2 ± 0.4	1.2 ± 1.1	7.5 ± 3.8	1.1 ± 1.0	12.5 ± 5.0		2.3 ± 0.9

	Hp^1	Hp^2	Hp^3	Hp^4	Hp^5	Hp^6	Hp^7	Hp^8	Hp^9	Ap^1	Ap^2	Ap^3	Ap^4	Ap^5	Ap^6	Ap^7	Ap^8	Ap^9
Hp^1		1+H+Off+Def	1	1+H+Off+Def	1	1+H+Off	1	1	1	1+H+Off+Def+H*Def	1+H+Off+Def	1	1	1	1+H	1		1+H
Hp^2	1+H+Off+Def		1+H+Off+Def	1+H+Off	1+H+Def	1	1+H	1+H	1	1+H+Def	1+H+Off+Def	1	1+H+Off	1+H+Off+Def+H*Off+H*Def	1+H	1	1+H+Def	1+H
Hp^3	1+H	1+H+Off+Def		1+H	1	1+H+Off+Def	1	1+H	1	1	1	1+H+Off+Def	1+H	1	1+H	1	1	1
Hp^4	1+H+Off+Def	1+H+Off	1+H+Off		1+H+Off+Def+H*Def	1+H+Off+Def	1+H+Off+Def	1+H+Off+Def	1	1+H+Off+Def	1+H+Off	1	1+H+Off+Def+H*Off	1	1+H	1	1	1
Hp^5	1+H+Off+Def	1+H+Off+Def	1+H+Off+Def	1+H+Off+Def		H+Off+Def+H*Def	1+H+Off	1+H+Off+Def	1+H+Off+Def	1+H+Off	1+H+Off+Def+H*Off	H+Off	1+H+Off+Def	1+H+Off+Def+H*Off+H*Def	1+H+Off+Def	1+H	1+H	1
Hp^6	1+H+Off+Def	1+H+Off+Def	1+H+Off	1+H+Off+Def	1+H+Off+Def		1	1+H+Off	H+Off+Def+H*Off	1+H+Off	1+H+Off+Def	1+H+Off+Def	1	1+H+Def	1+H+Off+Def+H*Def	1+H	1	1+H+Def
Hp^7	1+H+Off+Def	1+H+Off	H	1+H+Off+Def	1+H+Off	1+H		1+H+Off+Def	1+H+Off	1+H+Off	1+H	1	1+H+Off	1	1+H+Off	1+H+Off+Def	1	1
Hp^8	1+H+Off+Def	1+H+Off+Def	1+H+Off	1+H+Off	1+H+Off+Def	H+Off+Def+H*Off	1+H+Off+Def+H*Off		1+H+Off+Def	1+H+Off	1+H+Off+Def	1+H+Off+Def	H+Off+Def+H*Def	1	1+H+Def	1+H+Off+Def+H*Def	1+H+Off	1
Hp^9	1+H+Off	1+H+Off+Def	1+H+Off+Def	1	1+H	1+H+Off	1+H+Off	1+H+Off+Def		1+H	1+H+Off	1+H+Off	1	1+H+Off	1+H+Off+Def	1	1	1+H+Off
Ap^1	1+Off	1	1	1+Off+Def	1+Off	1	1+Off	1+Off	1		1+Off+Def	1+Off	1+Off	1	1	1+Off+Def	1+Off+Def	1+Off
Ap^2	1	1+Off	1+Off+Def	1+Def	1	1+Off+Def	1+Off+Def	1+Off+Def	1+Off	1+Off+Def		1+H+Off+Def+H*Off	1+Off+Def	1+Off+Def	1+Off	1+Off	1+Off+Def	1+Off+Def
Ap^3	1+Off	1	1	1+Off	1	1+Off	1	1	1+Off	1+Off+Def	1+Off+Def		1	1+Off	1+Off+Def	1	1+Off	1+Off+Def
Ap^4	1+Def	1	1	1+Off+Def	1	1	1	1+Off	1+Off+Def	1+Off+Def	1+Off	1+Off+Def		1+Off+Def		1+Off	1+Off	1+Off+Def
Ap^5	1	1	1	1+Off+Def	1+Off+Def	1+Off+Def	1+Off	1+Off+Def	1+Off	1+Def	1+Off+Def	1+Off+Def	1+Off+Def		1+Off+Def	1+Off+Def	1+Off+Def	1+Off
Ap^6	1	1	1	1	1	1+Off+Def	1	1+Off	Off+Def	1	1+Off+Def	1+Off+Def	1+Off+Def	1+Off+Def		1+Off	1+Off	1+Off+Def
Ap^7	1	1	1	1	1	1	1+Off+Def	1	1	1	1	1	1+Off+Def	1	1		1+Off+Def	1+Off+Def
Ap^8	1	1+Def	1	1	1+Off+Def	1+Off	1	1+Off+Def	1+Def	1	1	1	1	1+Def	1+Off	1+Off+Def		1+Off+Def
Ap^9	1		1	1	1	1	1+Off+Def	1+Off+Def		1	1	1	1+Off	1	1+Off+Def	1	1+Off+Def	

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3. Result
3.3 20-state model

Selection of Log-Linear Models

For goals

	H_G	A_G
H_p^1	0.05 ± 0.22	–
H_p^2	1.31 ± 1.29	–
H_p^3	0.04 ± 0.19	–
H_p^4	0.00 ± 0.06	–
H_p^5	0 ± 0	–
H_p^6	0.00 ± 0.06	–
A_p^4	–	0 ± 0
A_p^5	–	0 ± 0
A_p^6	–	0 ± 0
A_p^7	–	0.059 ± 0.26
A_p^8	–	1.196 ± 1.08
A_p^9	–	0.02 ± 0.14

	H_G	A_G
H_p^1	1+H	—
H_p^2	1+H+Off+Def	—
H_p^3	1	—
H_p^4	1+H	—
H_p^5		—
H_p^6	1	—
A_p^4	—	1
A_p^5	—	
A_p^6	—	1
A_p^7	—	1
A_p^8	—	1+Off+Def
A_p^9	—	1

For possession

	Hp^1	Hp^2	Hp^3	Hp^4	Hp^5	Hp^6	Hp^7	Hp^8	Hp^9	Ap^1	Ap^2	Ap^3	Ap^4	Ap^5	Ap^6	Ap^7	Ap^8	Ap^9	Time
Hp^1		15.1 ± 6.2	1.3 ± 1.2	8.4 ± 4.1						8.5 ± 3.6	4.6 ± 2.3								2.7 ± 1.0
Hp^2	8.6 ± 4.5		8.6 ± 4.4	1.6 ± 1.5	3.9 ± 2.5						17.6 ± 5.2			1.5 ± 1.3					2.6 ± 1.0
Hp^3	1.3 ± 1.2	14.3 ± 5.7				7.7 ± 4.3						7.9 ± 3.1							2.5 ± 0.8
Hp^4	19.1 ± 6.4	3.2 ± 2.1	1.1 ± 1.1		18.0 ± 9.9	1.8 ± 1.8	5.6 ± 3.1	3.0 ± 2.0		2.9 ± 1.9	1.3 ± 1.1		8.6 ± 3.6						4.7 ± 1.6
Hp^5	5.1 ± 2.7	6.6 ± 4.1	4.3 ± 2.4	20.2 ± 10.0		18.6 ± 9.3	1.0 ± 1.1	4.0 ± 2.7	1.1 ± 1.1		1.6 ± 1.3			4.7 ± 2.4					4.1 ± 1.6
Hp^6	1.1 ± 1.3	3.4 ± 2.0	17.8 ± 6.0	1.7 ± 1.6	16.7 ± 9.0			2.7 ± 2.2	5.7 ± 3.8		1.3 ± 1.2	3.0 ± 1.9			8.3 ± 4.0				4.4 ± 1.5
Hp^7				12.1 ± 4.4	2.4 ± 1.7			7.5 ± 4.5					1.9 ± 1.4			2.5 ± 1.9			1.9 ± 0.6
Hp^8	1.1 ± 1.3		1.0 ± 1.3	7.7 ± 3.3	11.9 ± 4.9	8.0 ± 3.6	8.7 ± 4.8		8.6 ± 4.6				1.1 ± 1.1		1.1 ± 1.1				3.5 ± 0.9
Hp^9					2.5 ± 1.8	12.0 ± 5.0		7.4 ± 4.7							1.9 ± 1.5			2.5 ± 1.8	1.8 ± 0.6
Ap^1	2.7 ± 2.0			2.2 ± 1.7							6.8 ± 4.2	0.5 ± 0.8	11.6 ± 4.4	2.2 ± 1.5		1.1 ± 1.2			1.8 ± 0.6
Ap^2		1.1 ± 1.2		1.2 ± 1.3		1.3 ± 1.3				8.6 ± 4.1		9.3 ± 4.8	8.1 ± 3.6	11.7 ± 4.9	8.2 ± 3.8		1.1 ± 1.4		3.6 ± 0.9
Ap^3			2.8 ± 1.9			2.1 ± 1.5					7.1 ± 4.1			2.4 ± 1.6	12.5 ± 4.7				1.9 ± 0.6
Ap^4				8.9 ± 3.6				1.3 ± 1.2		5.4 ± 3.2	2.7 ± 2.1			15.8 ± 9.0	1.5 ± 1.5	17.4 ± 6.1	3.4 ± 2.1		4.3 ± 1.4
Ap^5					5.1 ± 2.2			1.5 ± 1.3			4.1 ± 2.6	1.0 ± 1.1	18.3 ± 9.3		18.3 ± 9.5	4.2 ± 2.6	6.4 ± 3.8	4.3 ± 2.5	4.0 ± 1.9
Ap^6						8.7 ± 3.6		1.1 ± 1.1	3.0 ± 1.9		2.6 ± 1.9	5.7 ± 3.0	1.5 ± 1.5	16.8 ± 9.3		1.0 ± 1.1	3.0 ± 2.0	17.0 ± 6.3	4.5 ± 1.4
Ap^7							7.8 ± 3.2						7.6 ± 3.9				13.0 ± 5.5	1.3 ± 1.3	2.4 ± 0.9
Ap^8					1.3 ± 1.1			15.7 ± 4.8						3.8 ± 2.5	1.3 ± 1.2	7.8 ± 3.9		7.4 ± 3.7	2.4 ± 0.9
Ap^9								4.4 ± 2.2	8.0 ± 3.4						7.5 ± 3.8		12.5 ± 5.0		2.3 ± 0.9

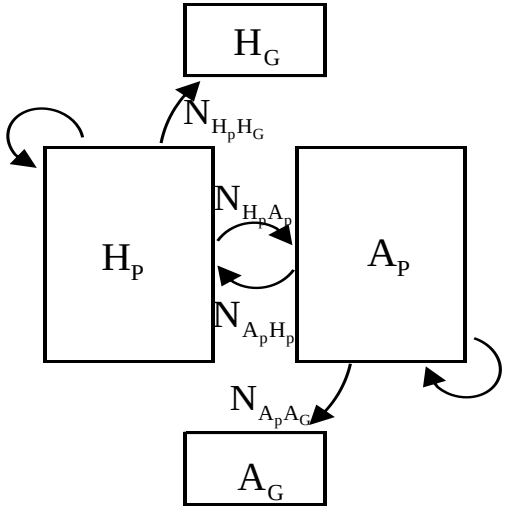
	Hp^1	Hp^2	Hp^3	Hp^4	Hp^5	Hp^6	Hp^7	Hp^8	Hp^9	Ap^1	Ap^2	Ap^3	Ap^4	Ap^5	Ap^6	Ap^7	Ap^8	Ap^9
Hp^1		1+H+Off+Def		1+H+Off+Def						1+H+Off+Def+H*Def	1+H+Off+Def							
Hp^2	1+H+Off+Def		1+H+Off+Def	1+H+Off	1+H+Def						1+H+Off+Def			1+H+Off+Def+H*Off+H*Def				
Hp^3	1+H	1+H+Off+Def		1+H		1+H+Off+Def						1+H+Off+Def						
Hp^4	1+H+Off+Def	1+H+Off	1+H+Off		1+H+Off+Def+H*Def	1+H+Off+Def	1+H+Off+Def	1+H+Off+Def		1+H+Off+Def	1+H+Off		1+H+Off+Def+H*Off					
Hp^5	1+H+Off+Def	1+H+Off+Def	1+H+Off+Def	1+H+Off+Def	H+Off+Def+H*Def	1+H+Off	1+H+Off+Def	1+H+Off+Def			1+H+Off+Def+H*Off			1+H+Off+Def+H*Off+H*Def				
Hp^6	1+H+Off+Def	1+H+Off+Def	1+H+Off	1+H+Off+Def	1+H+Off+Def		1+H+Off	H+Off+Def+H*Off			1+H+Off+Def	1+H+Off+Def		1+H+Def	1+H+Off+Def+H*Def				
Hp^7				1+H+Off+Def	1+H+Off		1+H+Off+Def						1+H+Off			1+H+Off+Def		
Hp^8	1+H+Off+Def	1+H+Off+Def	1+H+Off	1+H+Off	1+H+Off+Def	H+Off+Def+H*Off	1+H+Off+Def+H*Off		1+H+Off+Def				H+Off+Def+H*Def		1+H+Def				
Hp^9					1+H	1+H+Off		1+H+Off+Def							1+H+Off+Def			1+H+Off	
Ap^1	1+Off			1+Off+Def							1+Off+Def	1+Off	1+Off	1		1+Off+Def			
Ap^2		1+Off		1+Def		1+Off+Def				1+Off+Def		1+H+Off+Def+H*Off	1+Off+Def	1+Off+Def	1+Off	1+Off	1+Off+Def	1+Off+Def	
Ap^3						1+Off				1+Off+Def	1+Off+Def			1+Off	1+Off+Def				
Ap^4				1+Off+Def				1+Off		1+Off+Def	1+Off					1+Off	1+Off	1+Off	1+Off+Def
Ap^5					1+Off+Def			1+Off+Def			1+Off+Def	1+Off+Def	1+Off+Def	1+Off+Def	1+Off+Def	1+Off+Def	1+Off+Def	1+Off	1+Off
Ap^6						1+Off+Def		1+Off	Off+Def		1+Off+Def	1+Off+Def	1+Off+Def	1+Off+Def		1+Off	1+Off	1+Off+Def	1+Off+Def
Ap^7							1+Off+Def						1+Off+Def			1+Off+Def	1+Off+Def	1+Def	
Ap^8					1+Off+Def			1+Off+Def						1+Def	1+Off	1+Off+Def		1+Off+Def	
Ap^9								1+Off+Def	1+Off+Def						1+Off+Def		1+Off+Def		

4. Discussion
4.1 Home advantage

4-state model

For goals: $\log(N_{HpHG}/T_{Hp})=$

Model	Degrees of Freedom	Number of Parameters	logL*	Deviance -2logL*	Residual Deviance	AIC
1	611	1	-939.3	1878.6	797.4	1880.6
1+H	610	2	-938.9	1877.8	796.6	1881.8
1+H+Off	593	19	-922.4	1844.8	763.6	1882.8
1+H+Def	593	19	-922.0	1844.0	762.8	1882.0
1+H+Off+Def	576	36	-905.9	1811.9	730.7	1883.9
1+H+Off+Def+H*Off	559	53	-894.2	1788.4	707.3	1894
1+H+Off+Def+H*Def	559	53	-894.7	1789.4	708.2	1895
1+H+Off+Def+H*Off+H*Def	542	70	-883.7	1767.5	686.3	1907
1+H+Off+Def+H*Off+H*Def+Off*Def	271	341	-720.3	1440.6	359.5	2123
1+H+Off+Def+H*Off+H*Def+Off*Def+H*Off*Def	0	612	-540.6	1081.2	0	2305



$\text{Log}(N_{HpHG}/T_{Hp})=\lambda$

Model: 1

$N_{HpHG} / T_{Hp} = 430 / 8588.77$
$= 0.050$ [goals / min]

$N_{ApAG} / T_{Ap} = 390 / 8294.55$
$= 0.047$ [goals / min]

4. Discussion
4.1 Home advantage
8-state model

Transition Model achieving Min. AIC	Degrees of Freedom	Number of Parameters	logL*	Deviance −2logL*	Residual Deviance	AIC (Minimum)
H_p^F-->H_G 1+H+Off+Def	611	576	−932.1	1864.2	784.0	1936.2
H_p^F-->A_p^F 1+H+Off+Def+H*Def	611	559	−2232.0	4464.0	1033.3	4570.0
H_p^M-->H_p^F 1+H+Off+Def+H*Off+H*Def+Off*Def	611	271	−2063.7	4127.5	516.1	4809.5
H_p^D-->H_p^F 1+H+Off+Def+H*Def	611	559	−1442.9	2885.8	885.1	2991.8
H_p^D-->A_p^D 1+H+Off+Def	611	576	−1551.3	3102.6	865.2	3208.6

	Goals from H_p^F
Intercept λ^F:	−1.759
Home advantage λ^F_h:	−0.001

Team	Offence (λ^F_{off})	Defence (λ^F_{def})
S.Hiroshima	0.586	−0.396
R.Urawa	0.387	0.104
G.Osaka	0.162	−0.205
FCTokyo	0.041	−0.319
A.Kashima	0.095	0.069
F.Kawasaki	0.141	0.202
FM.Yokohama	−0.008	−0.303
B.Shounan	−0.167	−0.075
G.Nagoya	0.070	−0.035
R.Kashiwa	0.049	−0.033
S.Tosu	−0.056	0.162
V.Kobe	−0.005	0.191
V.Kofu	−0.341	−0.141
V.Sendai	0.059	0.013
A.Niigata	−0.100	0.299
Matsumoto	−0.177	−0.147
S.Shimizu	−0.112	0.440
FM.Yamagata	−0.623	0.174

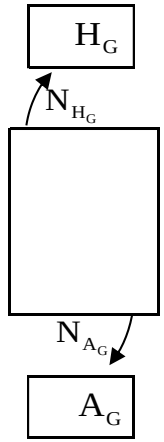
$$N_{Hp^F H_G} / T_{Hp^F} = 428 / 2372.67 = 0.180 \text{ [goals / min]}$$

$$N_{Ap^D A_G} / T_{Ap^D} = 390 / 2152.64 = 0.181 \text{ [goals / min]}$$

4. Discussion
4.1 Home advantage
3-state model

Model	Degrees of Freedom	Number of Parameters	logL*	Deviance −2logL*	Residual Deviance	AIC
1	611	1	−916.6	1833.2	752.0	1835.2
1+H	610	2	−915.6	1831.3	750.1	1835.3
1+H+Off	593	19	−883.5	1766.9	685.7	1804.9
1+H+Def	593	19	−900.3	1800.6	719.4	1838.6
1+H+Off+Def	576	36	−869.3	1738.7	657.5	1810.7
1+H+Off+Def+H*Off	559	53	−859.0	1717.9	636.7	1823.9
1+H+Off+Def+H*Def	559	53	−859.0	1717.9	636.7	1823.9
1+H+Off+Def+H*Off+H*Def	542	70	−850.6	1701.1	620.0	1841.1
1+H+Off+Def+H*Off+H*Def+Off*Def	271	341	−704.6	1409.2	328.0	2091.2
1+H+Off+Def+H*Off+H*Def+Off*Def+H*Off*Def	0	612	−540.6	1081.2	0	2305.2

	Goals
Intercept	λ : 0.202
Home advantage	λ_h : 0.098
Team	Offence (λ_{off})
S.Hiroshima	0.484
R.Urawa	0.456
G.Osaka	0.247
FCTokyo	0.028
A.Kashima	0.265
F.Kawasaki	0.349
FM.Yokohama	0.028
B.Shounan	−0.090
G.Nagoya	0.006
R.Kashiwa	0.050
S.Tosu	−0.168
V.Kobe	0.006
V.Kofu	−0.520
V.Sendai	0.006
A.Niigata	−0.065
Matsumoto	−0.313
S.Shimizu	−0.168
FM.Yamagata	−0.600

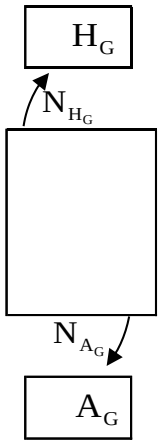


4. Discussion
4.1 Home advantage
3-state model

For goals

$$\log(N_{H_G}) = \lambda + \lambda_h + \lambda_{off}(X)$$

$$\log(N_{A_G}) = \lambda + \lambda_{off}(Y)$$



λ : Intercept for scoring goals ;

λ :Home-team advantage for scoring goals;

λ (X): Offensive strength of team X for scoring goals;

Home advantage of goals seems to be caused by the propensity for home team to have longer possession time in the F area, not strength of scoring .

4. Discussion
4.2 Analysis of characteristics of teams

8-state model

Transition Model achieving Min. AIC	Degrees of Freedom	Number of Parameters	logL*	Deviance −2logL*	Residual Deviance	AIC (Minimum)
H_p^F-->H_G 1+H+Off+Def	611	576	−932.1	1864.2	784.0	1936.2
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	Goals from H_P^F	
Intercept	λ^F:	−1.759
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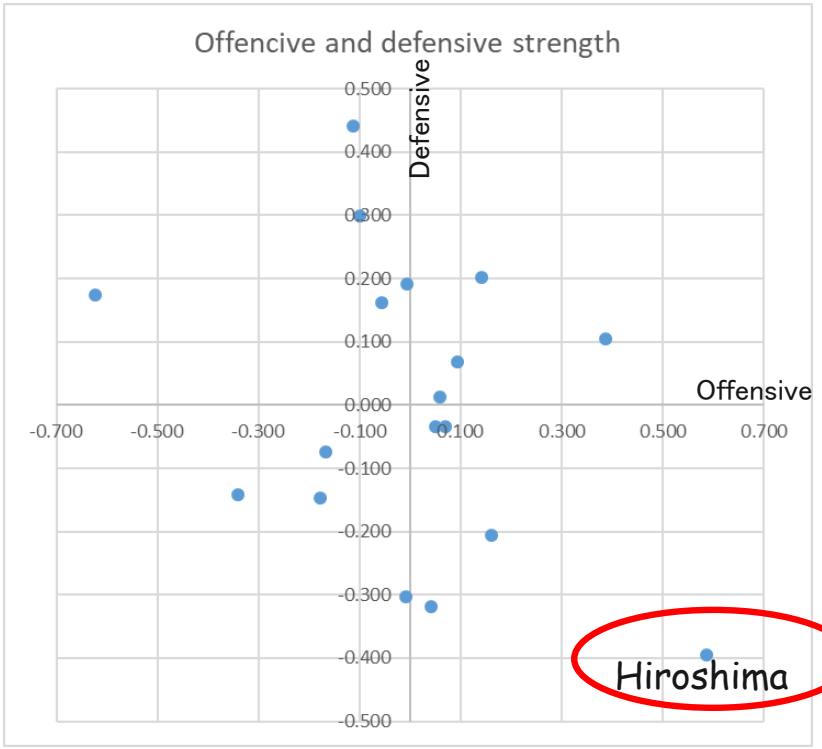
V.Kofu	−0.341	−0.141
V.Sendai	0.059	0.013
A.Niigata	−0.100	0.299
Matsumoto	−0.177	−0.147
S.Shimizu	−0.112	0.440
FM.Yamagata	−0.623	0.174

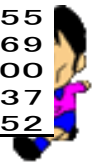


4. Discussion
4.2 Analysis of characteristics of teams

20-state model

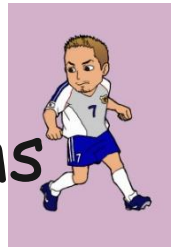
Transition	Model achieving Min. AIC	Degrees of Freedom	Number of Parameters	logL*	Deviance −2logL*	Residual Deviance	AIC (Minimum)
$H_p^2 \rightarrow H_G$	1+H+Off+Def	611	576	−945.7	1891.4	862.6	1963.4
$H_p^1 \rightarrow H_p^2$	1+H+Off+Def	611	576	−1687.3	3374.6	688.0	3446.6
$H_p^2 \rightarrow A_p^2$	1+H+Off+Def	611	576	−1816.9	3633.9	810.6	3705.9
$H_p^5 \rightarrow A_p^5$	1+H+Off+Def+H*Off+H*Def	611	542	−1454.7	2909.3	871.2	3049.3
$H_p^5 \rightarrow H_p^2$	1+H+Off+Def	611	576	−1531.1	3062.2	890.6	3134.2
$H_p^3 \rightarrow H_p^2$	1+H+Off+Def	611	576	−1666.4	3332.744	655.1	3404.7

	Transition from H_p^5 to H_p^2		Transition from H_p^1 to H_p^2		Transition from H_p^3 to H_p^2	
Intercept	μ^{H5H2}:	0.454	μ^{H1H2}:	1.696	μ^{H3H2}:	1.709
Home advantage	μ^{H5H2}_h:	0.016	μ^{H1H2}_h:	0.022	μ^{H3H2}_h:	0.046
Team	Offence (μ^{H5H2}_{off})	Defence (μ^{H5H2}_{def})	Offence (μ^{H1H2}_{off})	Defence (μ^{H1H2}_{def})	Offence (μ^{H3H2}_{off})	Defence (μ^{H3H2}_{def})
S.Hiroshima	−0.349	−0.038	0.062	0.026	0.134	−0.042
R.Urawa	−0.044	0.152	0.159	0.105	0.141	0.199
G.Osaka	−0.209	0.106	−0.140	0.013	−0.088	0.015
FCTokyo	−0.197	−0.116	−0.085	−0.031	−0.170	−0.009
A.Kashima	0.034	−0.167	−0.068	0.008	−0.010	−0.094
F.Kawasaki	0.274	0.043	−0.030	−0.061	0.131	0.028
FM.Yokohama	−0.174	−0.046	−0.070	−0.012	−0.044	−0.098
B.Shounan	0.209	0.091	−0.108	0.040	−0.051	−0.070
G.Nagoya	0.085	0.041	0.144	0.056	0.103	0.072
R.Kashiwa	0.006	−0.083	−0.081	0.029	−0.101	0.087
S.Tosu	0.118	−0.030	0.093	0.133	0.081	0.018
V.Kobe	0.214	0.134	0.000	0.053	−0.126	−0.011
V.Kofu	−0.225	0.032	0.003	−0.081	−0.212	0.033
V.Sendai	0.009	−0.008	−0.073	0.066	−0.025	0.055
A.Niigata	0.063	−0.016	0.000	−0.177	−0.020	−0.069
Matsumoto	0.063	0.173	0.166	−0.125	0.166	−0.100
S.Shimizu	0.148	−0.193	0.115	0.016	0.133	0.037
FM.Yamagata	−0.023	−0.075	−0.086	−0.058	−0.043	−0.052



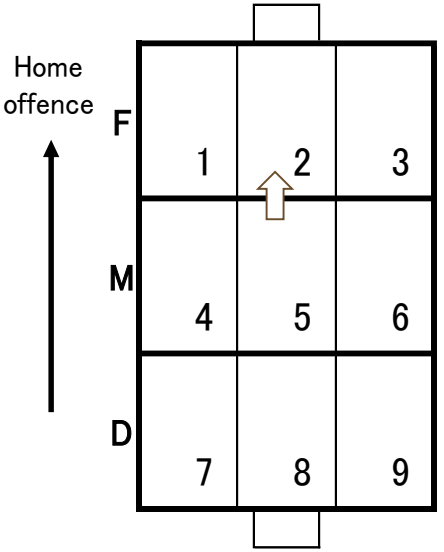
4. Discussion

4.2 Analysis of charc ams

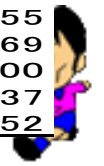


20-state model

Transition Model achieving Min. AIC		Degrees of Freedom	Numbe Parame	al ce	AIC (Minimum)
$H_p^2 \rightarrow H_G$	1+H+Off+Def	611	576	5	1963.4
$H_p^1 \rightarrow H_p^2$	1+H+Off+Def	611	576	0	3446.6
$H_p^2 \rightarrow A_p^2$	1+H+Off+Def	611	576	5	3705.9
$H_p^5 \rightarrow A_p^5$	1+H+Off+Def+H*Off+H*Def	611	542	2	3049.3
$H_p^5 \rightarrow H_p^2$	1+H+Off+Def	611	576	5	3134.2
$H_p^3 \rightarrow H_p^2$	1+H+Off+Def	611	576	1	3404.7

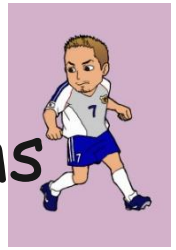


	Transition from H_p^5 to H_p^2		Transition from H_p^1 to H_p^2		Transition from H_p^3 to H_p^2	
Intercept	μ^{H5H2}:	0.454	μ^{H1H2}:	1.696	μ^{H3H2}:	1.709
Home advantage	μ^{H5H2}_h:	0.016	μ^{H1H2}_h:	0.022	μ^{H3H2}_h:	0.046
Team	Offence (μ^{H5H2}_{off})	Defence (μ^{H5H2}_{def})	Offence (μ^{H1H2}_{off})	Defence (μ^{H1H2}_{def})	Offence (μ^{H3H2}_{off})	Defence (μ^{H3H2}_{def})
S.Hiroshima	−0.349	−0.038	0.062	0.026	0.134	−0.042
R.Urawa	−0.044	0.152	0.159	0.105	0.141	0.199
G.Osaka	−0.209	0.106	−0.140	0.013	−0.088	0.015
FCTokyo	−0.197	−0.116	−0.085	−0.031	−0.170	−0.009
A.Kashima	0.034	−0.167	−0.068	0.008	−0.010	−0.094
F.Kawasaki	0.274	0.043	−0.030	−0.061	0.131	0.028
FM.Yokohama	−0.174	−0.046	−0.070	−0.012	−0.044	−0.098
B.Shounan	0.209	0.091	−0.108	0.040	−0.051	−0.070
G.Nagoya	0.085	0.041	0.144	0.056	0.103	0.072
R.Kashiwa	0.006	−0.083	−0.081	0.029	−0.101	0.087
S.Tosu	0.118	−0.030	0.093	0.133	0.081	0.018
V.Kobe	0.214	0.134	0.000	0.053	−0.126	−0.011
V.Kofu	−0.225	0.032	0.003	−0.081	−0.212	0.033
V.Sendai	0.009	−0.008	−0.073	0.066	−0.025	0.055
A.Niigata	0.063	−0.016	0.000	−0.177	−0.020	−0.069
Matsumoto	0.063	0.173	0.166	−0.125	0.166	−0.100
S.Shimizu	0.148	−0.193	0.115	0.016	0.133	0.037
FM.Yamagata	−0.023	−0.075	−0.086	−0.058	−0.043	−0.052



4. Discussion

4.2 Analysis of charc ams



20-state model

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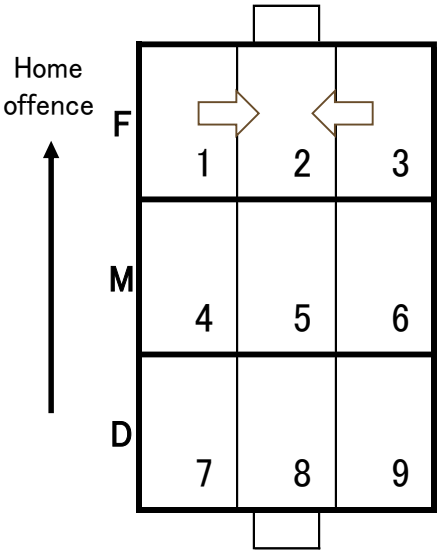
$H_p^2 \rightarrow H_G$	1+H+Off+Def	611	576	5	1963.4
$H_p^1 \rightarrow H_p^2$	1+H+Off+Def	611	576	0	3446.6
$H_p^2 \rightarrow A_p^2$	1+H+Off+Def	611	576	5	3705.9
$H_p^5 \rightarrow A_p^5$	1+H+Off+Def+H*Off+H*Def	611	542	2	3049.3
$H_p^5 \rightarrow H_p^2$	1+H+Off+Def	611	576	5	3134.2
$H_p^3 \rightarrow H_p^2$	1+H+Off+Def	611	576	1	3404.7



	Transition from H_p^5 to H_p^2		Transition from H_p^1 to H_p^2		Transition from H_p^3 to H_p^2	
Intercept	μ^{H5H2}:	0.454	μ^{H1H2}:	1.696	μ^{H3H2}:	1.709
Home advantage	$\mu^{H5H2}{}_h$:	0.016	$\mu^{H1H2}{}_h$:	0.022	$\mu^{H3H2}{}_h$:	0.046
Team	Offence ($\mu^{H5H2}{}_{off}$)	Defence ($\mu^{H5H2}{}_{def}$)	Offence ($\mu^{H1H2}{}_{off}$)	Defence ($\mu^{H1H2}{}_{def}$)	Offence ($\mu^{H3H2}{}_{off}$)	Defence ($\mu^{H3H2}{}_{def}$)
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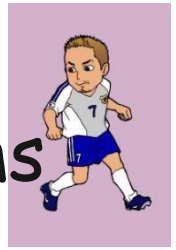
4. Discussion

4.2 Analysis of charc ams



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