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<b>16. Abstract</b>  <p>Periodic congestion of the locks in the Upper Mississippi River and Illinois Waterway negatively impacts inland waterway transport. Previous investigation of an appointment system, among other low cost measures, did not result in an acceptable resolution of the traffic issue. Responding to the continued need to improve management and reduce the operational costs of inland water transportation, this research project examines and evaluates alternative traffic management policies for implementation on the Upper Mississippi River (UMR) portion of the inland navigation system.</p> <p>To determine impact on lockage times and transit times, statistical analysis was conducted on different types of vessels using the system, different lockages required, night or day movements, and river flow characteristics. Based on this data, a discrete event simulation model was created and is presented as a tool for investigating traffic changes, explicitly incorporating seasonal and interdependent demands.</p> <p>Research results reveal that current low commercial traffic levels on the UMR system do not warrant implementing an alternative traffic management policy; benefits relative to cost and market disruptions are not sufficient. However, implementing a vessel tracking system may incur benefits of increasing homeland security, improving navigation safety, and protecting environmentally sensitive river habitats. Volume II, research results of a companion project investigating these possibilities, focuses on using vessel tracking with geographic positioning systems to improve operations and to enhance safety, security, and environmental protection of the UMR system.</p>			
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# **MANAGEMENT SYSTEMS FOR INLAND WATERWAY TRAFFIC CONTROL, VOLUME I: IDENTIFICATION AND EVALUATION OF ALTERNATIVES FOR MANAGING LOCK TRAFFIC ON THE UPPER MISSISSIPPI RIVER**

**Final Report  
November 2005**

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**Table 8. Selected summary statistics of wait time distributions by lock, direction, and lockage type for tows, 2000 through 2003**

<b>Lock</b>	<b>Direction</b>	<b>Lockage Type</b>	<b>Mean Wait Time (hours)</b>	<b>Number</b>	<b>Std Dev (hours)</b>
20	Downbound	Double	2.45	4358	5.52
		Knockout	2.90	126	3.81
		Other	2.61	90	2.81
		Single	1.29	1313	3.39
		Total	2.21	5887	5.08
	Upbound	Double	2.27	4162	2.96
		Knockout	2.32	92	2.26
		Other	2.36	116	2.73
		Single	1.00	1554	1.77
		Total	1.94	5924	2.74
21	Downbound	Double	2.01	4533	3.93
		Knockout	2.75	126	4.17
		Other	3.05	82	7.55
		Single	1.28	1289	2.21
		Total	1.89	6030	3.73
	Upbound	Double	2.17	4293	4.76
		Knockout	2.16	109	2.11
		Other	1.82	133	1.91
		Single	0.99	1466	1.91
		Total	1.87	6001	4.19
22	Downbound	Double	3.44	4546	3.95
		Jackknife	0.31	2	0.44
		Knockout	4.40	147	4.85
		Other	4.17	81	4.36
		Single	2.17	1029	3.21
	Upbound	Total	3.25	5805	3.90
		Double	3.90	4327	4.93
		Jackknife	1.35	1	-
		Knockout	4.12	114	4.26
		Other	3.63	138	3.69
24	Downbound	Single	1.77	1179	2.76
		Total	3.46	5759	4.61
		Double	3.64	4717	4.43
		Knockout	3.83	188	3.95
		Other	3.95	80	3.47
	Upbound	Single	1.47	1061	2.36
		Total	3.27	6046	4.20
		Double	3.98	4457	8.37
		Knockout	3.49	124	3.81
		Other	3.99	139	4.50
25	Downbound	Single	1.44	1271	2.91
		Total	3.43	5991	7.47
		Double	3.04	4738	3.99
		Jackknife	0.00	1	-
		Knockout	3.80	193	5.04
	Upbound	Other	3.29	78	3.63
		Single	1.40	1268	2.38
		Total	2.74	6278	3.82
		Double	4.35	4474	11.33
		Knockout	3.75	131	5.20
		Other	3.74	139	5.71
		Single	0.96	2037	2.03
		Total	3.31	6781	9.46

**Table 9. Selected summary statistics of lockage time distributions by lock, direction, and lockage type, 2000 through 2003**

Lock	Direction	Lockage Type	Mean Lockage Time (hours)	Number	Std Dev (hours)
20	Downbound	Double	1.89	4358	0.62
		Knockout	1.04	126	0.41
		Other	1.24	90	0.35
		Single	0.46	1313	0.38
		Total	1.55	5887	0.83
	Upbound	Double	1.81	4162	0.50
		Knockout	0.95	92	0.28
		Other	1.40	116	0.37
		Single	0.47	1554	0.47
		Total	1.44	5924	0.77
21	Downbound	Double	1.99	4533	0.48
		Knockout	1.00	126	0.35
		Other	1.30	82	0.41
		Single	0.47	1289	0.26
		Total	1.63	6030	0.77
	Upbound	Double	1.84	4293	0.53
		Knockout	0.99	109	0.37
		Other	1.45	133	0.36
		Single	0.46	1466	0.25
		Total	1.48	6001	0.75
22	Downbound	Double	2.16	4546	0.66
		Jackknife	1.39	2	1.03
		Knockout	1.36	147	1.16
		Other	1.39	81	0.38
		Single	0.64	1029	1.18
	Upbound	Double	1.86	5805	0.98
		Jackknife	2.01	4327	0.61
		Knockout	1.17	1	-
		Other	1.17	114	0.77
		Single	1.65	138	0.49
24	Downbound	Double	0.56	1179	0.65
		Jackknife	1.69	5759	0.85
		Knockout	2.10	4717	0.63
		Other	0.95	188	0.39
		Single	1.31	80	0.32
	Upbound	Double	1.31	80	0.32
		Knockout	1.78	6046	0.87
		Other	1.82	4457	0.46
		Single	1.05	124	0.47
		Total	1.43	139	0.35
25	Downbound	Double	0.48	1271	0.19
		Jackknife	1.51	5991	0.69
		Knockout	2.03	4738	0.65
		Other	1.75	1	-
		Single	0.94	193	0.49
	Upbound	Double	1.35	78	0.69
		Knockout	0.42	1268	0.27
		Other	1.66	6278	0.88
		Single	1.83	4474	0.61
		Total	1.01	131	0.40
		Other	1.57	139	0.97
		Single	0.38	2037	0.25
		Total	1.37	6781	0.85

*Distributions of Transit Times between Locks for Commercial Tows*

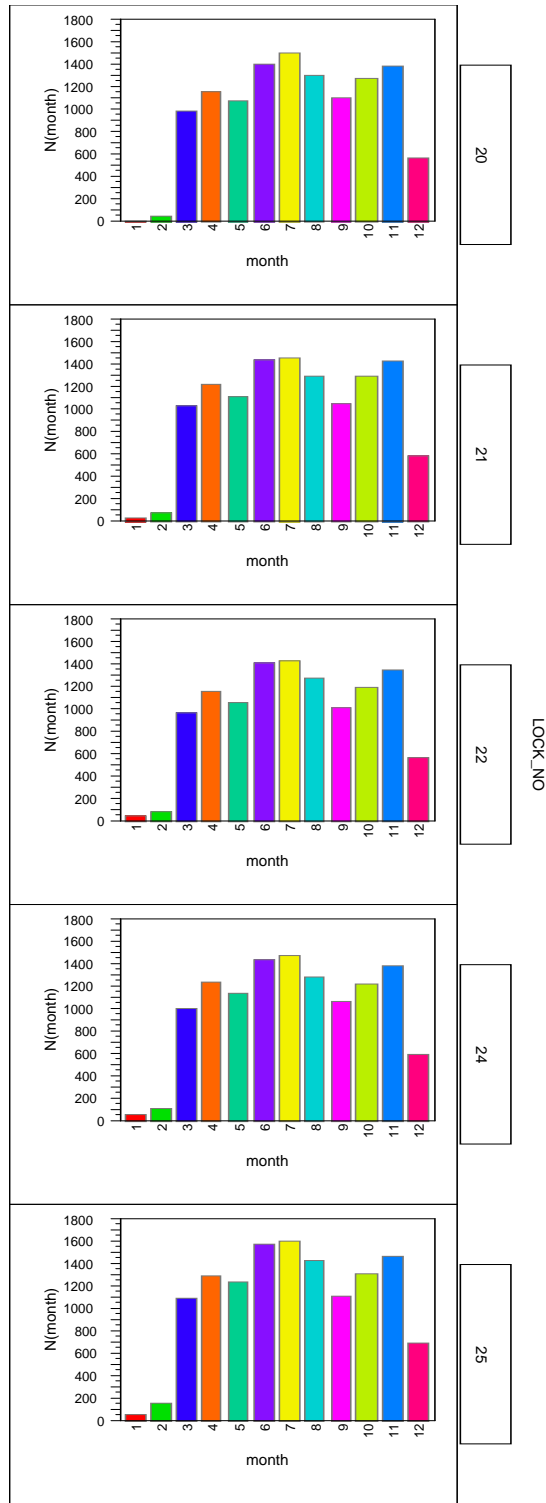
The implied transit time for vessels moving through the pools connecting the locks may be estimated as the amount of time observed between the recorded arrival time at a lock for a vessel and the recorded end of lockage time at the previous lock transited by that vessel. These implied travel times often include many different activities undertaken by vessels between consecutive appearances at UMR locks as not all commercial tows move non-stop from one lock in the system to another lock in the system. These implied pool transit times are estimated for all multi-cut and single cut tow lockage sequences observed in the database. Estimates of implied transit times are not computed for other vessel transits because the majority of other vessel lockages in the system involve the lockage of recreation craft where a unique identification of the vessel involved in the lockage is not contained in the data. Also excluded from these implied transit time estimates are tow lockage sequences identified in the data with an implied negative travel time from one lock to another and tow lockage sequences that are physically impossible. For example, an observed tow transit consisting of a downbound lockage at UMR Lock 22 followed sequentially by an upbound lockage at UMR Lock 24 is excluded from the travel time estimates as such a tow movement is physically impossible (without an intervening lockage). Inspection of the data reveals that the anomalous tow lock transitions and negative tow travel times are most likely created by miscoded vessel identification numbers, miscoded lockage and arrival dates, and the fact that not all tow identification numbers are recorded for all light boats moving through a lock together in multiple vessel lockages.

The distributions of implied tow transit times are generated for each possible combination of origin lock, destination lock, lockage type (single cut or multi-cut tow at the destination lock), direction of travel at the origin lock, and direction of travel at the destination lock. The summary statistics of these distributions are displayed in Table 10 for multi-cut and single cut tows.

**Table 10. Selected summary statistics of transit times between locks for multi-cut and single-cut tows that continue directly to the next lock without stopping, 2000 through 2003**

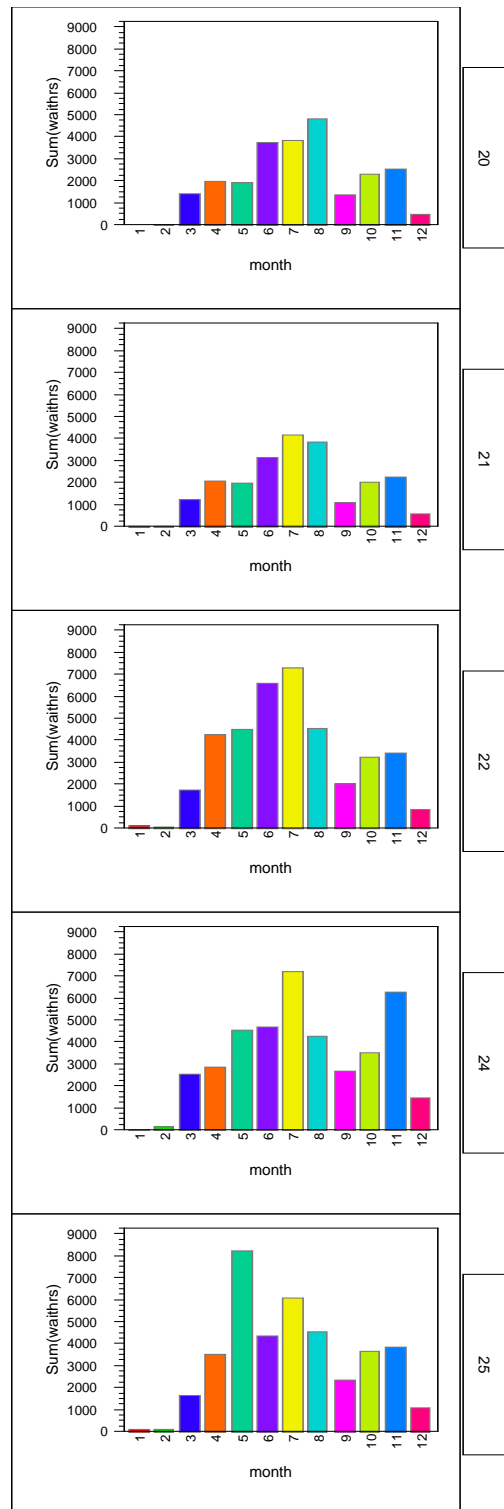
<b>Lockage Type</b>	<b>Destination Lock</b>	<b>Destination Direction</b>	<b>Previous Lock</b>	<b>Previous Direction</b>	<b>Mean Transit Times (hours)</b>	<b>Number</b>	<b>Std Dev (hours)</b>
<b>Double</b>	20	Upbound	21	Upbound	3.80	3236	4.11
	21	Downbound	20	Downbound	2.50	3536	3.21
	21	Upbound	22	Upbound	4.74	3863	2.61
	22	Downbound	21	Downbound	3.07	4096	1.85
	22	Upbound	24	Upbound	5.57	3343	9.36
	24	Downbound	22	Downbound	3.95	3907	1.39
	24	Upbound	25	Upbound	7.09	4266	3.39
	25	Downbound	24	Downbound	4.38	4523	1.58
<b>Single</b>	20	Upbound	21	Upbound	5.44	562	16.86
	21	Downbound	20	Downbound	10.18	501	93.07
	21	Upbound	22	Upbound	5.98	356	10.78
	22	Downbound	21	Downbound	4.16	274	10.99
	22	Upbound	24	Upbound	5.54	542	17.00
	24	Downbound	22	Downbound	4.82	518	28.21
	24	Upbound	25	Upbound	5.82	694	4.38
	25	Downbound	24	Downbound	5.59	615	24.80





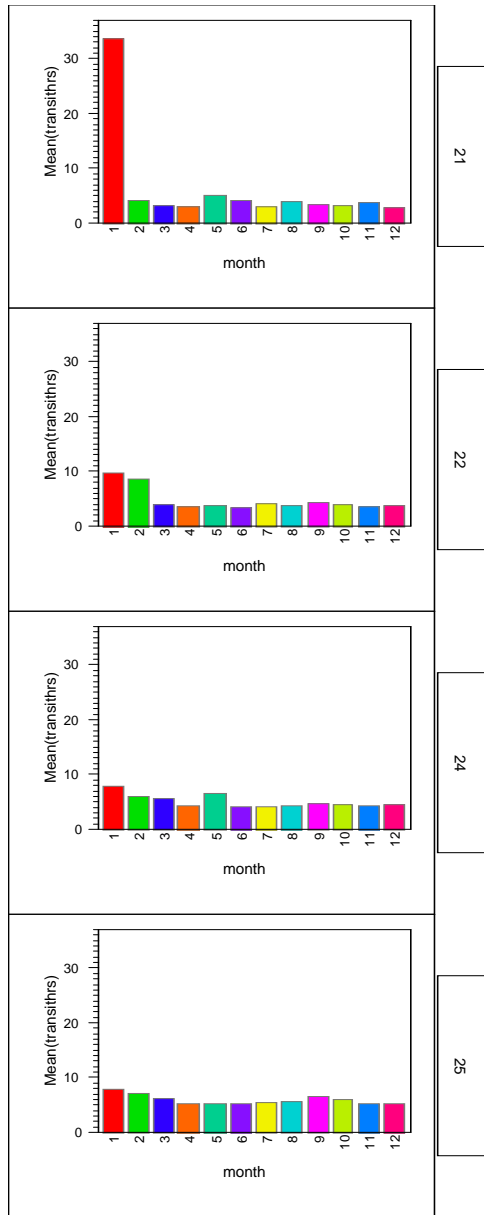
**Figure 5. Number of lockages at UMR locks 20 through 25 by month, 2000 through 2003**

Figure 6 displays the aggregated wait for lockage times characterized by the month of lockage summed over all vessels using each of the locks during the period from 2000 through 2003.



**Figure 6. Aggregated wait for lockage times (hours) for all vessels by lock and month, 2000 through 2003**

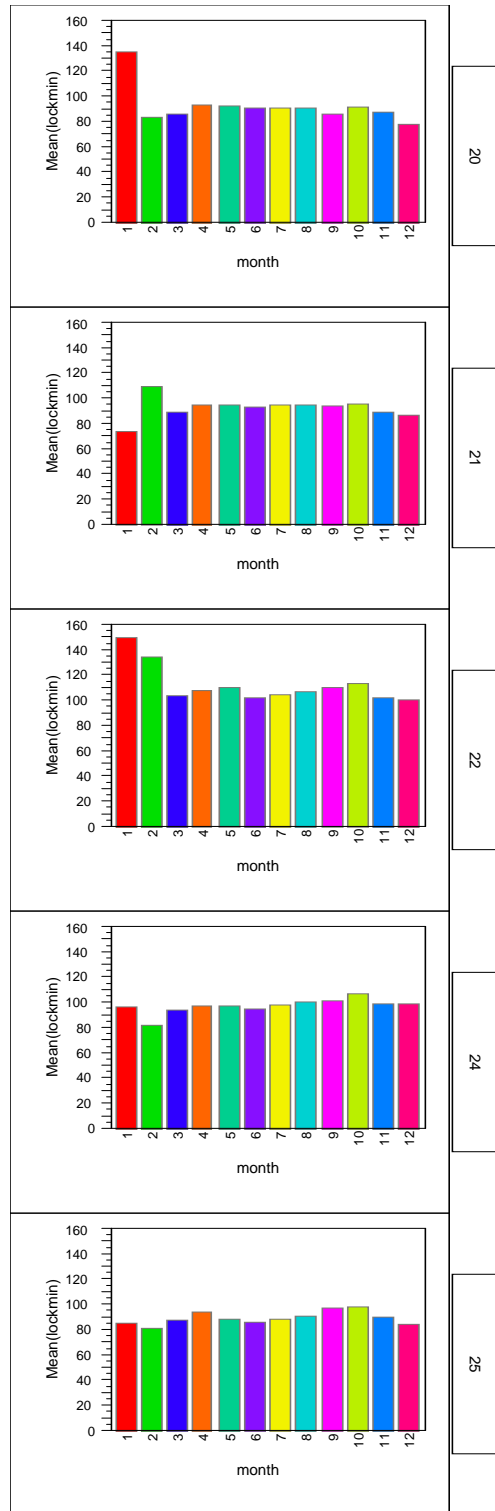




**Figure 7. Mean pool transit times (hours) for commercial tows by month, 2000 through 2003**

Figure 8 displays the mean lockage times for tows by month for each of the locks during the period from 2000 through 2003. There is little evidence of seasonality present in the monthly distributions of mean tow lockage times observed at each of the locks.





**Figure 8. Mean lockage times (minutes) for tows at UMR locks 20 through 25 by month, 2000 through 2003**









**Table 11. Selected summary statistics of lockage time distributions for tows traveling downbound, 2000 through 2003**

Lock	Lockage Type	Operations Type	Mean Lock Time (hours)	Number	Std Dev (hours)
20	Double	EXCHANGE	1.89	1691	0.76
		FLY	2.00	1207	0.57
		TURNBACK	1.82	1460	0.45
	Knockout	EXCHANGE	1.10	44	0.43
		FLY	1.13	26	0.47
		TURNBACK	0.95	56	0.33
	Other	EXCHANGE	1.18	34	0.35
		FLY	1.36	18	0.26
		TURNBACK	1.23	38	0.39
	Single	EXCHANGE	0.46	414	0.29
		FLY	0.50	496	0.54
		TURNBACK	0.40	403	0.17
21	Double	EXCHANGE	1.93	1746	0.47
		FLY	2.25	1288	0.42
		TURNBACK	1.83	1499	0.46
	Knockout	EXCHANGE	1.01	42	0.34
		FLY	1.27	31	0.43
		TURNBACK	0.84	53	0.18
	Other	EXCHANGE	1.28	26	0.39
		FLY	1.59	18	0.53
		TURNBACK	1.17	38	0.28
	Single	EXCHANGE	0.44	449	0.27
		FLY	0.56	418	0.29
		TURNBACK	0.41	422	0.20
22	Double	EXCHANGE	2.14	1874	0.57
		FLY	2.52	934	0.86
		TURNBACK	2.00	1738	0.56
	Jackknife	FLY	2.12	1	-
		TURNBACK	0.67	1	-
	Knockout	EXCHANGE	1.53	62	1.58
		FLY	1.52	25	0.51
		TURNBACK	1.11	60	0.72
	Other	EXCHANGE	1.39	34	0.38
		FLY	1.68	12	0.28
		TURNBACK	1.29	35	0.36
	Single	EXCHANGE	0.51	377	0.28
FLY		0.98	245	2.10	
TURNBACK		0.56	407	0.84	
24	Double	EXCHANGE	2.16	1824	0.62
		FLY	2.18	909	0.70
		TURNBACK	2.01	1984	0.59
	Knockout	EXCHANGE	0.95	66	0.29
		FLY	0.97	35	0.23
		TURNBACK	0.94	87	0.49
	Other	EXCHANGE	1.33	33	0.33
		FLY	1.40	11	0.35
		TURNBACK	1.27	36	0.29
	Single	EXCHANGE	0.51	407	0.62
		FLY	0.57	313	0.29
		TURNBACK	0.54	340	0.92
25	Double	EXCHANGE	2.03	2325	0.47
		FLY	2.35	697	0.70
		TURNBACK	1.89	1716	0.77
	Jackknife	FLY	1.75	1	-
	Knockout	EXCHANGE	1.08	79	0.67
		FLY	1.04	24	0.28
		TURNBACK	0.80	90	0.24
	Other	EXCHANGE	1.28	32	0.32
		FLY	1.57	11	0.21
		TURNBACK	1.35	35	0.98
	Single	EXCHANGE	0.42	423	0.27
		FLY	0.49	401	0.31
TURNBACK		0.37	444	0.20	

**Table 12. Selected summary statistics of lockage time distributions  
for tows traveling upbound, 2000 through 2003**

Lock	Lockage Type	Operations Type	Mean Lock Time (hours)	Number	Std Dev (hours)
20	Double	EXCHANGE	1.93	1594	0.41
		FLY	1.91	1109	0.59
		TURNBACK	1.60	1459	0.45
	Knockout	EXCHANGE	1.02	24	0.30
		FLY	1.00	22	0.18
		TURNBACK	0.90	46	0.31
	Other	EXCHANGE	1.64	39	0.39
		FLY	1.41	28	0.29
		TURNBACK	1.21	49	0.29
	Single	EXCHANGE	0.48	570	0.50
		FLY	0.51	601	0.54
		TURNBACK	0.38	383	0.15
21	Double	EXCHANGE	1.93	1730	0.40
		FLY	2.01	1153	0.61
		TURNBACK	1.58	1410	0.48
	Knockout	EXCHANGE	1.13	36	0.36
		FLY	1.18	22	0.39
		TURNBACK	0.82	51	0.27
	Other	EXCHANGE	1.55	54	0.39
		FLY	1.61	36	0.25
		TURNBACK	1.21	43	0.27
	Single	EXCHANGE	0.43	573	0.25
		FLY	0.56	494	0.28
		TURNBACK	0.37	399	0.14
22	Double	EXCHANGE	2.13	1780	0.51
		FLY	2.28	775	0.62
		TURNBACK	1.78	1772	0.62
	Jackknife	EXCHANGE	1.17	1	-
	Knockout	EXCHANGE	1.48	35	1.25
		FLY	1.19	16	0.39
		TURNBACK	1.00	63	0.33
	Other	EXCHANGE	1.78	61	0.58
		FLY	1.76	24	0.36
		TURNBACK	1.46	53	0.35
	Single	EXCHANGE	0.49	525	0.26
		FLY	0.83	297	1.17
TURNBACK		0.43	357	0.24	
24	Double	EXCHANGE	1.91	1772	0.51
		FLY	1.94	848	0.36
		TURNBACK	1.68	1837	0.42
	Knockout	EXCHANGE	1.11	46	0.57
		FLY	1.32	22	0.41
		TURNBACK	0.90	56	0.32
	Other	EXCHANGE	1.51	53	0.37
		FLY	1.51	27	0.38
		TURNBACK	1.31	59	0.30
	Single	EXCHANGE	0.46	542	0.19
		FLY	0.56	347	0.21
		TURNBACK	0.43	382	0.17
25	Double	EXCHANGE	1.94	1802	0.59
		FLY	2.05	809	0.75
		TURNBACK	1.62	1863	0.49
	Knockout	EXCHANGE	1.17	49	0.42
		FLY	1.19	25	0.39
		TURNBACK	0.79	57	0.27
	Other	EXCHANGE	1.61	56	0.54
		FLY	2.00	22	1.63
		TURNBACK	1.39	61	0.92
	Single	EXCHANGE	0.37	693	0.18
		FLY	0.41	804	0.23
		TURNBACK	0.35	540	0.33





























































































































