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PREPARATION OF THE TRAFFIC ACCIDENT ESTIMATING MODEL WITH THE DISCRETE EVENT SYSTEM SIMULATION

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KESİKLİ OLAY SİSTEM SİMÜLASYONU İLE TRAFİK KAZA TAHMİN MODELİNİN KURULMASI

ÖZET

Bu çalışmanın amacı, trafik kaza analizleri sonucunda elde edilen verilerin değerlendirilerek, kaza tahmin modellerinin kurulmasıdır. Bu sebeple, D100 karayolu üzerinde belirlenen kesimlerde meydana gelen kazalar çarpışma diyagramları ve kaza özet tabloları yardımıyla değerlendirilerek simülasyon uygulaması için veri tabanı oluşturulmuştur. Toplanan bu veriler kesikli olay sistem simülasyonu ile değerlendirilerek sistemi yansıtan simülasyon modeli kurulmuştur. Model yardımı ile incelenen kesimlerde herhangi bir iyileştirme yapılması ya da yapılmaması durumunda bir yıl içinde meydana gelebilecek kazaların durumları ortaya çıkarılmıştır.

SUMMARY

The object of this study is to establish an estimation model for traffic accidents with the help of the data that is gathered from the analysis of traffic accidents which took place at the black spots that were determined by ranking and quality control methods. In order to serve this end, a data base for simulation application has been set up by evaluating the accidents that took place at the appointed black spots with site analysis method. By evaluating the gathered data with discrete event simulation, a model that reflects the system has been set up. With the help this model, the situation of the potantial accidents that may take place in a period of one year, should an improvement at the inspected spots is made or not, has been revealed.

1. INTRODUCTION

Concerning the preparation of the traffic accident estimating models or the accident models, macroscopic models have been developed up to now and regression techniques have been applied during the stages of model preparation. The usage of simulation techniques in dealing with the transportation problems has become very important today. However, simulation applications to the transportation problems, which require complete approaches, have not been developed yet.

In this study, simulation application results developed according to the data acquired from a road section, which had been examined using the site analysis, will be given.

2. THE EVALUATION OF THE TRAFFIC ACCIDENTS IN TURKEY

As it's known, the most important criterion of the highway safety is traffic accidents. From this point of view, Turkey is in a bad condition with regard to developed countries. The most important reason for this is that the present passenger and good traffic is not properly balanced in the transportation systems. The distribution of the passenger and the good traffic according to the transportation types is shown on the Table 2.1.

Table 2.1. The distribution of the passenger and the good traffic according to the transportation types

Transportation Systems	1993				1994				1995			
	ton.km $x10^6$	%	pas.km $x10^6$	%	ton.km $x10^6$	%	pas.km x106	%	ton.km $x10^6$	%	pas.km x106	%
Highway	97,843	91.1	146.029	94.2	95.020	91.2	140.743	94.2	112,515	92.5	155.202	94.8
Railway	8511	7.9	7147	4.6	8338	8.0	6335	4.2	8632	7.1	5797	3.5
Seaway	901	0.8	53	0.1	587	0.6	47	0.1	276	0.2	61	0.1
Airway	152	0.2	1721	1.1	198	0.2	2268	1.5	231	0.2	2666	1.6
Total	107,407	100	154,95	100	104,143	100	149,393	100	121,654	100	163,726	100

As a result of this unbalanced distribution the vehicle density on the highways is increasing. Thus, the traffic accidents are increasing as well. The values related to the accidents in Turkey are shown on the Table 2.2.

Table 2.2. The variations in the amount of accidents, deaths and injuries between years 1995 - 1999

Years	Accident		Deaths		Injury	
	Number	(%)	Number	(%)	Number	(%)
1995-1996	64978	23,23	-576	-9,59	-9720	-8,50
1996-1997	42892	12,45	-247	-4,55	1547	1,48
1997-1998	52616	13,58	-246	-4,75	8406	7,92
1998-1999	-1811	-0,41	-339	-6,87	-4653	-4,06

3. SYSTEM SIMULATION

Simulation is the process of mathematical operations describing the model of an actual process or system **due to time period**. In order to prepare a system model or to obtain a result in a simulation, the system concept should be thoroughly examined. System can be defined as the combination of the elements such as human, machine or vehicle, which are related with each other. The system is sometimes affected by the other changes and thus, the modeling studies are affected as well. So, utmost care should be taken when making decisions about the environment and limits of the system. Many descriptions should be taken into account to define and analyze a system. Miscellaneous examples of these descriptions for various systems are shown on the Table 3.1

Table 3.1. System and system components

SYSTEM	ELEMENTS	FEATURES	ACTIVITIES	EVENTS	STATE VARIABLE
Bank	Customers	Balance control	Money deposit	Arrival, Departure	Number of customers to be served
Railway	Train	Origin, Destination	Travel	Arrival, Departure to stations	Number of trains waiting at each stations
Highway	Vehicles	Vehicle x km	Travel	Traffic accident	Interval between accidents
Production	Machines	Speed, Capacity	Source, combining	Defective	Machinery status
Communication	Messages	Distance, goal	Dialing	Reaching target	The number to dial
Inventory	Warehouse	Capacity	Outgoing supplies	Demand	Level of inventory

3.1. System Types:

Systems are divided into two categories as discrete and continuous. In the discrete system, state variables momentarily change at the discrete points with time. On the other hand, the state variables continuously change in the continuous systems. Since only one type of change is effective in all systems, a few systems are completely discrete or continuous in practice. The system examined in this study is completely discrete.

3.2. Simulation of Discrete Event:

Simulation models are dynamic and they define the system behavior depending on time. The state variable at the end of a specific period is accepted as input for the system analysis and by the means of this input, the state of the system in the future is acquired.

Simulation of the discrete event is the modeling of the systems in which the state variables momentarily change with time. One single event occurs at these points with time and thus the event variable changes. Simulation models are set to work bearing in mind some initial conditions. The choice of the initial conditions depends on the researched system behaviors. System behaviors fall into two categories, which are:

1. System behaviors related with the transient state conditions
2. Behaviors related with the steady state conditions

Transient state conditions can be described as the temporary behaviors at the moment the system initially works. The type of behavior changes into a steady state after the initial start of the system. The system behaviors after this moment are the behaviors related with the steady state conditions. The length of the simulation should be decided before the simulation model is set to work. The analyzer should determine state conditions that he is going to use (transient or steady) prior to the afore mentioned decision. After determining the state conditions, the point at which the transient from the transient state conditions to the steady state conditions takes place should be determined.(Fig.3.1) If the transient conditions are chosen, the initial conditions are accepted as a reflection of the system. Under these circumstances, the system is stopped as the steady state conditions are reached. In another application this system can be set to work according to the steady state conditions without taking the transient state conditions into consideration. In this study the transient from transient state conditions to the steady state condition is calculated by the application of the Welch method. The simulation method, thus, is operated according to the steady state conditions.

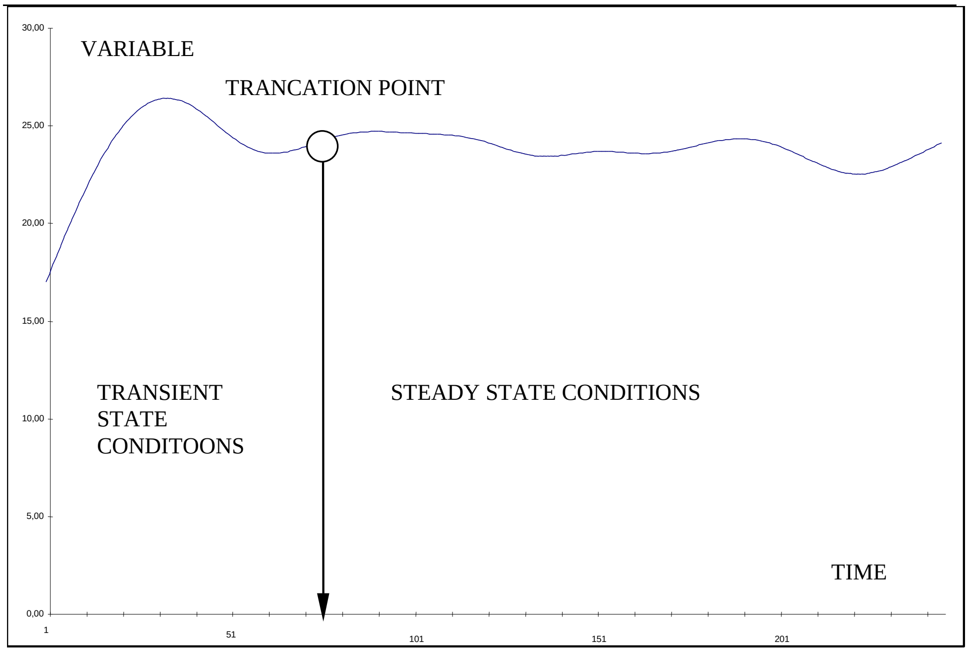

Figure 3.1. Transition from transient conditions to the steady state conditions.

4. APPLICATION OF THE SYSTEM SIMULATION.

4.1. Preparation of the database:

At the beginning of the study, the necessary studies that should be carried out in terms of road safety and the traffic engineering and the methods to be used in the study has been determined. The Ranking and the Quality Control Methods has been used to find out black points and the Site Analysis have been applied for bringing the real causes of accidents into light. As the study area, Göztepe - Tuzla section of D100 State Highway (in Istanbul) has been chosen. Following this determination, approximately 3000 accident reports covering the accidents which happened in this sections in 1994 have been evaluated and all information about the accidents have been transferred to the collision diagrams with the accident summary tables. Firstly, the actual causes of these accidents and the improvements to eliminate these causes are determined by means of the data acquired from the diagrams. The data acquired from the accident reports are then used in the simulation.

4.2. Preparation of the simulation table

Bearing in mind that the simulation is the process of mathematical operations describing the model of an actual process or system due to time period; the interval between the accidents in the sections are accepted as the basic variables in the initial stage of simulation. The interval between the accidents is calculated in hours every month for a year. Then, by using a computer package program it's examined on which statistical distribution the interval between accidents confirm. As a result, it's found out that the interval between accidents comply with exponential distribution. In preparing the simulation table, the condition of the weather during the accident and the types of collisions along with the types of vehicles are accepted as the variables apart from the basic variable (interval between the accidents).

On the other hand, the following stages are followed in preparing the simulation table:

Since the periods between the accidents comply with the exponential distribution, the distribution was transferred to the simulation table as a function of the average and the random number chosen by the computer.

$$\textit{Interval between accidents} = \mu . \ln(R)$$

Where;
μ : Average of the distributions
R : Random number (interval between the accidents)

The weather conditions at the time of the accident (sunny, rainy, cloudy) was accepted as the second variable, and the model intervals which will operate the decision mechanism to the random number determined by the computer, distribution percentages and the cumulative totals of the accidents were calculated to be transferred to the simulation table according to the weather conditions.

Types of accidents in the sections depending on the weather conditions were accepted as the third variable. Then, the distribution percentages, cumulative totals and the model intervals of the types of accidents were calculated. Maximum 7 collision types were considered for each section in calculating the model intervals.

A: Right angle collision
B : Rear end collision
C : Head on collision
D : Pedestrian struck by m.v.
E : m.v. Collided with fixed objects
F : m.v. Collided with parked m.v.
G: Out of control
I: Overturned vehicle
J: Slide swipe
K: Side swipe
L: Left turn head on collision
M: Right turn head on collision

Then, these model intervals were transferred to the simulation table. Thus, an accident was designed corresponding each random number determined by the computer. (See Table 4.1)

Table 4.1. The distribution percentage, cumulative totals and model intervals of collision types depending on the weather conditions.

Weather Conditions	GOZTEPE			
	Collision Type	(%)	Cum. Tot	Model interval
SUNNY (A)	B	36,37	36,37	0 - 36,37
	D	5,34	41,71	36,371 - 41,71
	E	9,62	51,33	41,711 - 51,33
	G	10,16	61,49	51,331 - 61,49
	I	3,2	64,69	61,491 - 64,99
	K	22,47	87,16	64,991 - 87,16
	L	12,83	100	87,161 - 100
RAINY (Y)	B	42,55	42,55	0 - 42,55
	E	10,64	53,19	42,551 - 53,19
	G	21,27	74,46	53,191 - 74,46
	H	2,12	76,58	74,461 - 76,58
	J	3,19	79,77	76,581 - 79,77
	K	13,83	93,6	79,771 - 93,6
	L	6,38	100	93,601 - 100
CLOUDY (B)	B	33,33	33,33	0 - 33,33
	C	11,11	44,44	33,331 - 44,44
	E	11,11	55,55	44,441 - 55,55
	G	22,22	77,77	55,551 - 77,77
	K	22,23	100	77,771 - 100

The types of the vehicles involved in the accidents were added to the simulation table as the last variable. Distribution percentage, cumulative totals and the model intervals of the vehicles involved in the accidents in the sections were calculated. (See Table 4.2.)

Model intervals (probability interval of the occurrence of an accident according to the variables) belonging to the four variables mentioned above were transferred to the simulation table. As a random number was transferred by the simulation table, an accident in accordance with the probability or model intervals occurred.

Table 4.2. Distribution percentage, cumulative totals and the model intervals of the vehicles involved in the accidents

		BOSTANCI	GÖZTEPE	KÜÇÜKYALI	MALTEPE	GÜLSUYU	KARTAL	TOPSELVİ	PENDİK	PEN.KÖP.KAV.	TUZLA
Types of whichles involved in the accidents (%)	Car	59	63,6	62,4	62,53	64	58	45	48	49,3	61
	Truck	9	5,33	12	11,98	12	10,34	20	14,7	14,3	21
	Small Truck	12,5	8,45	12,4	12,42	8	14,42	12,5	12	11,2	10
	Small Bus	10,7	8,1	5,7	5,66	9,3	10,34	7,5	5,3	10,84	4,9
	Bus	8	7,17	7	6,97	6,7	4,7	12,5	17,3	11,2	1,6
	Taxi		5,7								
	Others	0,9	1,65	0,5	0,44		2,2	2,5	2,6	3,15	1,6
Cumulative Total	Car	59	63,6	62,4	62,53	64	58	45	48	49,3	61
	Truck	68	68,93	74,4	74,51	76	68,34	65	62,7	63,6	82
	Small Truck	80,5	77,38	86,8	86,93	84	82,76	77,5	74,7	74,8	92
	Small Bus	91,2	85,48	92,5	92,59	93,3	93,1	85	80	85,6	96,9
	Bus	99,2	92,65	99,5	99,56	100	97,8	97,5	97,3	96,84	98,5
	Taxi		98,35								
	Others	100	100	100	100		100	100	100	100	100
Model interval	Car	0-59	0-63,6	0-62,4	0-62,53	0-64	0-58	0-45	0-48	0-49,3	0-61
	Truck	59,001-68	63,601-68,93	62,401-74,4	62,531-74,51	64,001-76	58,001-68,34	45,001-65	48,001-62,7	49,301-63,6	61,001-82
	Small Truck	68,001-80,5	68,931-77,38	74,401-86,8	74,511-86,93	76,001-84	68,341-82,76	65,001-77,5	62,701-74,7	63,601-74,8	82,001-92
	Small Bus	80,501-91,2	77,381-85,48	86,801-92,5	86,931-92,59	84,001-93,3	82,761-93,1	77,501-85	74,701-80	74,801 - 85,64	92,001-96,9
	Bus	91,201-99,2	85,481-92,65	92,501-99,5	92,591-99,56	93,301-100	93,101-97,8	85,001-97,5	80,001-97,3	85,641-96,84	96,901-98,5
	Taxi		92,651-98,35								
	Others	99,201-100	98,351-100	99,501-100	99,561-100		97,801-100	97,501-100	97,301-100	96,841-100	98,501-100

Table 4.3. Simulation table

RND1	Interval Between the Accidents	Total Interval Between the Accidents	RND2	Weather Cond.	RND3	Types of Accidents Dependig on the Weather Conditions			RND4	Type
						Sunny	Rainy	Cloudy		
0,02	381,64	381,64	0,90	B	50,45	----	----	B	67,53	K
0,62	45,09	426,72	0,72	A	16,64	B	----	----	34,44	O
0,42	81,46	508,19	0,84	Y	70,93	----	K	----	79,56	K
0,62	44,91	553,09	0,06	A	48,41	B	----	----	50,60	O
0,08	232,05	785,14	0,15	A	19,70	B	----	----	19,66	O
0,10	220,80	1005,94	0,98	B	25,01	----	----	B	95,11	M
0,84	16,09	1022,03	0,73	A	70,22	E	----	----	15,99	O
0,44	78,11	1100,14	0,67	A	80,92	E	----	----	42,48	O
0,43	79,25	1179,39	0,84	Y	76,96	----	K	----	97,66	Ot
0,10	213,80	1393,18	0,39	A	84,23	G	----	----	29,54	O
0,06	261,82	1655,01	0,73	A	83,20	G	----	----	73,07	K
0,25	132,18	1787,19	0,23	A	3,70	B	----	----	4,08	O
0,09	222,30	2009,48	0,65	A	39,39	B	----	----	95,87	M
0,02	367,22	2376,71	0,43	A	22,03	B	----	----	19,49	O
0,70	33,93	2410,64	0,54	A	24,37	B	----	----	26,58	O
0,51	62,75	2473,39	0,88	B	90,11	----	----	K	32,17	O
0,98	1,86	2475,24	0,30	A	7,81	B	----	----	54,82	O
0,20	153,07	2628,32	0,90	B	68,47	----	----	B	87,47	Ky
0,45	74,17	2702,48	0,35	A	61,26	E	----	----	96,85	M
0,88	11,94	2714,42	0,23	A	31,59	B	----	----	70,84	K
0,66	39,23	2753,65	0,27	A	51,33	B	----	----	87,03	Ky
0,23	138,00	2891,65	0,93	B	78,45	----	----	K	51,27	O
0,66	39,35	2931,00	0,12	A	85,26	G	----	----	25,56	O
0,17	165,44	3096,44	0,37	A	35,38	B	----	----	54,34	O
0,80	21,11	3117,55	0,90	B	13,90	----	----	B	18,39	O
0,82	19,19	3136,74	0,49	A	94,75	I	----	----	98,71	D
0,55	55,85	3192,59	0,14	A	70,02	E	----	----	19,96	O
0,78	23,45	3216,04	0,22	A	45,61	B	----	----	19,82	O

Symbol of the Vehicles Type. O = Car, K=Truck, Ky=Small Truck, Ot=Bus, M=Small Bus, T=Taxi, D=Others

4.3. Calculation of the simulation length

After the simulation table had been set to work, simulation lengths were calculated by the determination of the points of transient from transient state conditions to the steady state conditions by the Welch method.

After the procedure, which had been carried out by means of moving averages acquired according to the Welch method, it was accepted that the examples in transient conditions had not reflected the system; on the other hand steady state conditions had reflected the actual system. Thus, the examples in transient conditions were eliminated and the averages of the remaining examples were taken. The calculated averages represent the values of the variables in the system a year later unless an improvement is carried out in the sections. These values are shown on table 4.4., 4.5., 4.6., 4.7.

Table 4.4. The Collision Types Distribution percentage, which accidents will occur after a year depending on weather, conditions if the section doesn't improved.

		BOSTANCI	GÖZTEPE	K.YALI	MALTEPE	GÜLSUYU	KARTAL	TOPSELVİ	PENDİK	PEN.KÖP.KAV.	TUZLA
SUNNY	A			2,61			6,96			13,15	
	B	35.08	35.39	81,46	80,25	58,35	21,72	48,59	52,85	34,25	60,93
	C					4,24	11,14				
	D	15.79	6.87		4,81		38,16	14,07	27,72	20,79	
	E	11.58	7.56	12,27			12,81	10,44	3,37		17,94
	F					4,48		5,22			
	G	5.96	9.27		3,29	9,97		8,43		4,59	9,83
	I		3.09					6,83			11,3
	K	31.59	24.39	3,66	11,65	8,72	3,62		13,21	27,22	
	L		13.43			8,47	5,59	6,42	2,85		
	M					5,77					
RAINY	A					15,38					
	B	43,9	43,33	73,68	60	17,94	28,77	61,7	30,23	74,19	
	C				8,57	7,69					
	D	14,63					28,77			6,46	
	E		12	10,52	14,28		8,22	16,31	39,54		56,25
	G	19,51	17,33	1,75	11,43	30,76				7,52	
	H		3,33								
	I				5,72		15,06	11,35			
	J		3,33								
	K	21,96	14,67	14,05		28,23	19,18	10,64	30,23	11,83	43,75
	L		6,01								
CLOUDY	A					30				1,67	
	B	38,83	17,24	53,33	75		22,22	55		63,33	74,2
	C		17,24	3,33			38,89				
	D	21,67		6,67	10	25	27,78			35	
	E		27,59						21,95		
	G		13,79			40			56,1		
	I							45			25,8
	K	20	24,14	36,67	15	5	11,11		21,95		
	L										
	M	20									

Table 4.5. The accident distribution percentage, which accidents will occur after a year depending on weather conditions if the section doesn't, improved.

SECTION	**WEATHER CONDITION**		
	SUNNY	**RAINY**	**CLOUDY**
BOSTANCI	73,83	10,62	15,54
GÖZTEPE	61,91	31,91	6,18
KÜÇÜKYALI	81,49	12,13	6,38
MALTEPE	84,04	7,45	8,51
GÜLSUYU	87,17	8,47	4,36
KARTAL	79,77	16,22	4,01
TOPSELVİ	60,73	34,39	4,88
PENDİK	82,12	9,15	8,73
P.K.KAV.	68,13	19,38	12,5
TUZLA	81,24	6,38	12,38

Table 4.6. Types of vehicle distribution percentage, which accidents will occur after a year if the section doesn't, improved.

	TYPES OF VEHICLE						
SECTIONS	CAR	TRUCK	S. TRUCKS	S. BUS	BUS	TAXI	OTHER
GÖZTEPE	62,97	4,89	6,38	10,85	8,51	4,91	1,49
BOSTANCI	58,72	8,08	12,13	11,91	8,09	---	1,06
KÜÇÜKYALI	59,14	13,4	13,4	6,17	6,38	---	1,51
MALTEPE	66,81	8,72	12,55	6,38	5,54	---	---
GÜLSUYU	63,91	11,3	9,13	10,43	5,23	---	---
PENDİK	50,21	14,25	12,34	3,4	17,45	---	2,35
PEN.KÖP.KAV.	53,96	14,38	11,87	6,67	10,2	---	2,92
KARTAL	57,33	10,67	16,22	10,89	3,55	---	1,34
TOPSELVİ	45,12	21,95	13,41	6,34	10,73	---	2,45
TUZLA	60,88	22,35	9,18	3,39	2,39	---	1,81

Table 4.7. Sample numbers reflecting the system and the averages of the interval between accidents (hour).

SECTIONS	**SIMULATION LENGTH(STEP)**	**AVERAGES of the PRESENT STATE**	**AVERAGES of the SIMULATION**
GÖZTEPE	470	23.79	23.69
BOSTANCI	386	33.64	33.60
KÜÇÜKYALI	470	25.84	26.01
MALTEPE	470	21.32	20.45
GÜLSUYU	460	84.33	86.10
KARTAL	450	19.68	19.65
TOPSELVİ	410	105.00	100.52
PENDİK	470	77.88	76.33
PEN.KÖP.KAV.	480	18.00	18.29
TUZLA	490	94.00	94.31

4.5. Simulation results.

With the modeling study data of the accidents happening in the sections, which are examined by the site analysis, are evaluated and information is acquired about the accidents to happen in the future unless an improvement is carried out. Moreover, the form of the simulation model enables us to obtain the results of the various improvements to be made. At the end of an improvement procedure, the effect of the Improvement on the accidents can be seen upon the transfer of the pre-determined changes in the model intervals to the simulation table.

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