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Petri Ağları Kullanılarak Akıllı Trafik Sinyalizasyon Kontrolü

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Trafik ışıkları kontrolü,
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ÖZET

Ulaşım araçları, insanların ihtiyaçlarını ve mallarını bir alandan diğer bir alana taşımak amacıyla kullanılan araçları ifade etmektedir. Trafikteki araç sayılarının artması, kullanılan yollar etrafındaki alanların yetersizliği ve bu yolların genişletilememesi veya alt/üst yollar yapılamaması sebebiyle akıllı trafik sinyalizasyon sistemlerine ihtiyaç duyulmaktadır. Günümüzde, trafik sistem mekanizmalarının sabit zamana bağlı olması sebebiyle trafik kontrolünün mevcut yoğunlukta yetersiz kaldığı durumlar oluşmaktadır. Bundan dolayı zaman kaybını ve ekonomik sorunları engelleyebilmek için birtakım akıllı yöntemler geliştirilmiştir.
Bu çalışmada dört yollu bir kavşaktaki trafik ışıklarının akıllı denetimi için günün belirli saatlerinde toplanmış gerçek verilere dayanarak Petri Ağlarının (PA) uygulaması yapılmıştır. PA'nın performansları, klasik (sabit süreli) performansları ile karşılaştırılmıştır. Elde edilen sonuçlar hem geçen araç sayısı hem de zaman açısından değerlendirildiğinde PA 755 sn'de 849 araç, klasik yöntemde 920 sn'de 341 araç geçişi gerçekleştiği ve PA ile daha iyi sonuç elde edildiği görülmüştür.

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Intelligent Traffic Signaling Control Using Petri Nets

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ABSTRACT

Transportation vehicles refer to the vehicles used to transport people's needs and goods from one area to another. Intelligent traffic signaling systems are needed due to the increase in the number of vehicles in traffic, the roads used, the insufficiency of the surrounding areas and the inability to widen these roads or construct upper / lower roads. Nowadays, there are situations where traffic control is insufficient in current density due to the traffic system mechanisms being dependent on fixed time. Therefore, some smart methods have been developed to prevent waste of time and economic problems. In this study, application of Petri Nets (PA) based on real data collected at certain times of the day for intelligent control of traffic lights at a four-way intersection. PA's performances have been compared with their classical (fixed time) performances. When the results obtained were evaluated in terms of both the number of passing vehicles and time, it was seen that the PA passed 849 vehicles in 755 seconds, 341 vehicles in 920 seconds in the classical method and a better result was obtained with PA.

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1. INTRODUCTION *(GİRİŞ)*

It is used to direct traffic headings and pedestrians, which are the most important part of the traffic flow, and to manage the traffic smoothly, especially at intersections. Ensuring that the appropriate traffic lights intersection

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efficiency is optimized and intersections are found. The beginnings of traffic control signals are based on manual semaphores in early 1868, and the first traffic signal was used in America. It was first used in green and red traffic books in 1868 in London. Those cars were not motor vehicles yet invented. He was driving cars. They were trying to regulate the traffic with gas lamps on the roads where the cars were busy. Upon these problems, the first electric traffic light was used for railway signaling in the USA in 1914. In New York in 1918, a three-color traffic light was used, similar to the traffic lights we use today. A similar system was established in 1920 in England. In 1925, the first electromagnetic traffic control in Melbourne in Australia was used. [1-3].

The normal function of traffic lights requires advanced control and coordination to ensure that traffic moves as smoothly and safely as possible and that pedestrians are protected when crossing roads. To achieve this, different control systems are used, from simple clock mechanisms to complex self-adjusting computerized control and coordination systems that minimize delay for people using the road [4]. A number of designs and studies were carried out before the traffic light became the reliable system known today.

Traffic density in the morning and evening hours of the intersections in the center of Ankara city was observed. In order to reduce the density, a mathematical model has been developed to reduce the waiting time of the vehicles and to determine the cycle time and green time [1]. In order to prevent traffic congestion, a vehicle count was made in the morning and evening hours when the traffic density at the "Topraklık Crossroad" and "City Crossroads" in Denizli peaks. Considering the count results, optimum signal durations have been determined for the relevant intersections [5]. Traffic light signal or stop lamp; It is defined as a signaling device positioned at road intersections, pedestrian crossings, and other places that control the movement of vehicles and pedestrians. Also, Traffic lights normally have three main lights: Red, light meaning "Stop", green light meaning "go", and yellow light meaning "stop if possible". There are two common strategies used to control traffic: Fixed Time (FT) based traffic light control mechanism and Real Time (RT) based traffic light algorithm [6]. The Genetic Algorithm Model has been introduced to provide an intelligent green range response based on dynamic traffic control inputs to the traffic density control system, thus overcoming the inefficiency of traditional traffic controllers. In this way, difficulties are solved when the number of vehicles is read in four directions from the sensors in each lane, and when the two lanes are motivated at the junction and the pedestrian road junction [7]. The study where traditional traffic signal control methods based on fixed time models could not effectively deal with the variable and complex traffic situation, any traffic flow was modeled according to a predetermined cycle time and the signal was changed without creating an analysis. Fuzzy rule-based controllers have proven to be good managers of the traffic light system in different scenarios [8-10]. A prototype system for controlling traffic at the intersection is designed using the VB6 Matlab tool. The traffic intersection is simulated in VB6 and the data about the traffic parameters are collected in the VB6 environment. The decision on the extension period is made using the Matlab tool. This decision is based on Arrivals and Sequences of vehicles imported from VB6 environment in Matlab. The delay time experienced by vehicles using fixed traffic control is compared to observe fuzzy traffic control activity. An isolated Traffic Junction simulation was made in the Visual Basic 6 environment. It has been observed that the fuzzy controller is more effective than the fixed control [11] . This work proposed a two-stage traffic light system for real-time traffic control. Alam, which aims to dynamically direct the phase and green time of an isolated signalized traffic light, in order to reduce the average vehicle delay in different traffic flow rates; used two traffic emergency decision module (TUDM) and extension time decision module (ETDM) at the intersection. In the first phase, TUDM calculates the urgency for all red phases. Based on the degree of emergency, it creates a red light cycle for significant traffic urgency encountered in the next step of the transition. In the second step, ETDM calculates the green light; The emergency phase, depending on the number of vehicles, depends on the extension time. Said software was developed in Matlab to simulate the state of an isolated signal junction unit based on fuzzy logic. The two-stage traffic light system using fuzzy logic has outperformed models using fixed time systems, even systems operated by vehicles, thanks to the flexibility of the system. [12]. This article developed the traffic model and traffic controller model using Matlab software. It is based on the single-output and multiple-input queuing theory model. "SimEvent" toolbox is used in Matlab. The traffic controller has been developed in Matlab using the method of fuzzy logic application. Sensors that detect emergency vehicle movement are ambulance, fire brigade, police, etc. gives priority to vehicles and transmits the preferred signal according to the urgency and shape of the situation [13]. A new model that controls intersection in main streets has been introduced. In the model based on the idea of providing smart traffic lights for each intersection, traffic lights can predict the traffic density, send parameters to the control center and

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receive them from the control center. This intersection control system can be simulated with the CPN modeling tool to monitor the accuracy of the system performance. Color Petri Net (CPN) can be used to simulate different systems in order to eliminate possible defects in the system and even provides the opportunity to examine various input parameters [14]. It focuses on the use of Petri nets (PN) to model the control of signaled intersections. PN is a model dependent on the implementation of an eight-phase traffic signal controller. Structural analysis of the Control PN model was carried out to show how the model applies traffic operation safety rules [15]. To effectively control traffic signs at intersections, they presented an adaptive fuzzy color Petri Net system based on learning. The basis of the proposed algorithm is a combination of fuzzy logic and the learning automaton. This system is used to organize membership functions in the fuzzy system [16]. The control (signal plan) is pre-calculated using statistical data. It uses the preset cycle time (fixed time) to change the duration of the traffic lights according to this plan. In addition to ensuring the safety of road crossings, traffic lights ensure that the total time spent by all vehicles in the network is minimized, provided that the optimum control strategy is implemented. It is stated that it is used for the control or modification of real-time data related to traffic processes [17]. In this article reviewed focus on the development of Petri models and vehicles for the control and performance analysis of signalized traffic intersections and connected intersection networks. The potential of Petri nets as a single representation for many tools to address traffic network problems is discussed. These tools, to provide urban traffic network control; It provides control design, analysis, modeling, performance evaluation and direct control code generation. For the purpose of performance evaluation, a colorful Petri network model of the urban traffic network is presented and this network is discussed. Six examples of intersecting urban networks are provided to illustrate subnets, and an example step is given to show how subnets work together. This network was used as an input in a simulation using POSES to evaluate the performance of various control strategies. Thus, it was observed that the waiting times of the cars in traffic decreased.[18] .

In this study, Petri net networks method is applied for a single junction. While using the Petri net network method, unlike other studies, not only the green light duration was calibrated according to the intensity, the traffic lights of the roads were also controlled according to the density of the cars. In this study, the modeling of Petri net networks was carried out using MATLAB Simulink. When the real data and the data obtained from the modeling were compared, it was seen that the control method using petri dishes gave better results than the classical method.

2. MATERIAL and METHODS *(MATERYAL VE METOD)*

2.1. Traffic Signaling *(Trafik Sinyalizasyonu)*

The normal function of traffic lights requires advanced control and coordination to ensure that traffic moves as smoothly and safely as possible and that pedestrians are protected when crossing roads. To achieve this, different control systems are used, from simple clock mechanisms to complex self-adjusting computerized control and coordination systems that minimize latency for people using the road.

2.1.1. Traffic control types *(Trafik kontrol çeşitleri)*

Many different applications are used for traffic flow control. However, the structures of these applications are based on two main methods. These are fixed time and dynamic control methods [4].

2.1.1.1. Constant time control *(Sabit zaman kontrolü)*

The simplest control system uses a timer (fixed time): Each phase of the signal lasts for a specified time before the next phase occurs. This model repeats itself regardless of the traffic situation. Many older traffic light installations still use these methods. However, the signal timing of an intercept is a control system with disadvantages as it cannot be adapted to changing dominant flows throughout the day [19].

2.1.1.2. Dynamic control *(Dinamik kontrol)*

Dynamic or activated signals are programmed to automatically adjust their timing and phase to match changing traffic conditions. The system adjusts the timing and signal phase in order to minimize the delay of

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vehicles passing through the crossing point. It is also often used to change the control strategy of a traffic light depending on the time of day, day of the week, or other specific conditions such as an unusual situation at an intersection. The controller processor programs the signal timing within specified limits through sensors that report the presence of vehicles or other road users. It can give more time for a heavy traffic junction or shorten or skip a phase with little or no traffic waiting for a green light. The detectors used at this point are divided into three classes: Detectors embedded in the road, detectors on the road, and detectors that detect non-motorized vehicles [20].

2.2. Petri Nets *(Petri Ağları)*

Petri Networks is a mathematical and graphical modeling technique that helps modeling and performance evaluation of dynamic and discrete event systems.Since the 1960s, Petri networks have been used in the design, analysis and control of synchronous, asynchronous, stochastic systems. Petri Nets are divided into graphical and mathematical. Graphical petri nets show the visual state of the system. The mathematical model enables the development of algebraic relationships of state equations that show the behavior of the system [21]. This shows that Petri Nets can be used in both qualitative and quantitative analysis. Qualitative analysis evaluates the accuracy of the system and quantitative analysis evaluates the efficiency of the system [22].

The advantages of Petri Networks for discrete event systems can be listed as follows: [23], Petri Nets can be used to monitor systems in real time. Petri Nets can be used to monitor systems in real time.

- Complex features such as asynchronous operations, conflict, mutual exclusion, parallelism, priority relationships, stochasticity in the system to be modeled can be easily modeled with Petri Networks.
- Unwanted situations in the system can be easily detected by modeling the Petri network.
- Control codes can be created from the Petri network model.
- Discrete event simulation can be performed using the Petri net model directly.

Although Petri nets were originally developed for discrete event systems, they can be used for continuous and hybrid systems. Using techniques such as time, color, hierarchy, and blurring shows that Petri nets gradually increase the modeling ability.

2.1.1. Description of Petri Net *(Petri Ağının Tanımı)*

A Petri net, "N", is a double-sided, weighted, oriented multiple graph mathematically represented by a four-part N = (P, T, I, O). Here

Node definition

P = { p1, p2 ,..., pi ,..., pn } is a finite set of places

$P \cup T \neq \varnothing$ T = { t1,t2 ,...,t j ,...,tm } is a finite set of transitions

$P \cap T = \varnothing$

OK definition

$I : (P \times T) \rightarrow$ N+

N+ = {0,1,2,....}

$O : (P \times T) \rightarrow$ N+

The node definition states that the location set and the transition set are discrete (have no common elements) and that there is at least one node (x ∈ P ∪T) in the network. The arrow set (F) defines two types of functions: the input function (I) and the output function (O).

These input and output functions define the flow of tokens from places to passes and from passages to places. Notice that F ⊆ (P × T) U (T × P). Again | P | = n and | T | = m means that an ordinary Petri net has n places and

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m transitions. This notation will be used in later discussions. A general place element is denoted by pi and a general transition is denoted by tj. As mentioned earlier, i = 1,2,… .., n and j = 1,2,… .., m.

Petri prefers to use the OK set (F) and a weight function (W) instead of using the input-output functions (I and O) in the net definition. In this notation, a Petri net is represented by the quartet, N = (P, T, F, W), where F ⊆ (P × T) U (T × P) defines the flow relationship, W: F → N + a weight function , N + = {1, 2,3,… arrow weight is defined as follows. If $I(pi,tj)=k$, where k> 1 is an integer, it is drawn with a OK directed to the transition from pi to tj. If k = 1, an unlabeled arrow is drawn and OK does not pull if it happens when k = 0. An ordinary Petri net is mathematically described by four factors, where all arcs are unity-weighted (and therefore untagged). $N = (P,T,I,O)$, burada $P, \forall t \in T,\ I\ (p,\ t) \ \leq\ 1\ ve\ O\ (p,\ t)\ \leq\ 1$ [24].

2.3. Traffic Signaling Control with Petri Networks *(Petri Ağları ile Trafik Sinyalizasyon Kontrolü)*

In this study, the control study of traffic lights at the 4-way Sıhha intersection in Palestine, Alhalil city shown in Figure 1 with petri nets with a smart control mechanism is presented. The data used in this study were obtained on 18/09/2018, when the traffic is at its peak, at 12, 16 and 20 hours on Tuesday. The results obtained from the Petri Nets simulation performed with the MATLAB program used as an intelligent signaling controller were compared with the actual data.

Figure 1. Sanitary junction

In the petri net simulation given in Figure 2 using the MATLAB program, it was decided which street would be selected according to the vehicle density and how many seconds the green duration would be. As seen in Figure 2, the system consists of four parts. First, we start from the function part. In this section, real traffic data are used as green time (GT), yellow time (YT), Token (TK) and traffic data (Y). The green duration is 10 seconds and the yellow duration is 5 seconds. As mentioned earlier, no firing takes place in petri nets without a signal. For this reason, it is assumed to be a sign as a starting point.

```
function [GT,YT,TK,y]= fcn()
%#codegen
 Data=load('TrafficData.mat');

GT=uint32(1000);
YT=uint32(50);
TK=true;
%Data.carsCount(1,1);
y =Data.carsCount;
```

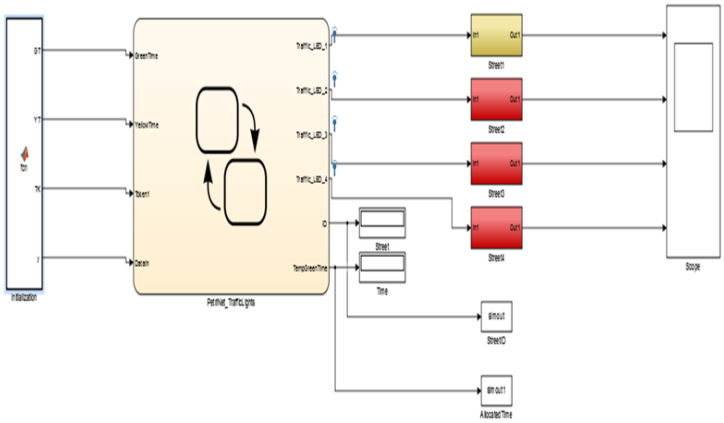

Figure 2. Smart traffic signaling using Petri network method

The net graph of the petri dish created for a single intersection of the simulation given in Figure 2 is given in Figure 3.

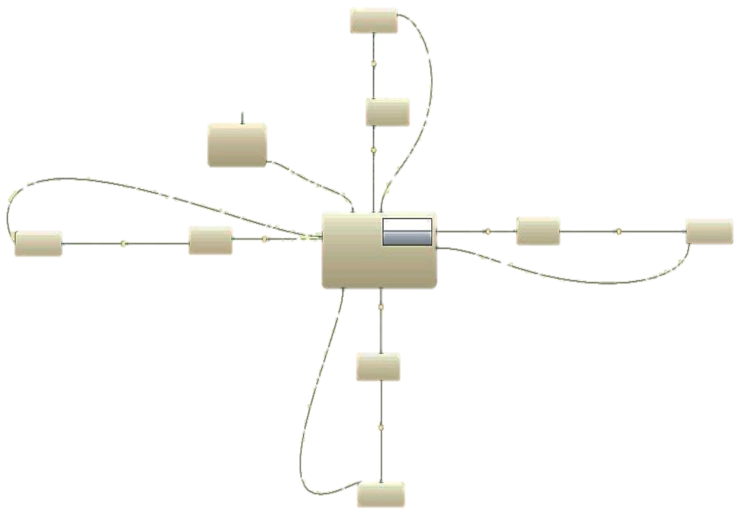

Figure 3. Petri net graph for single junction.

The working principle of the Petri net graphic is first started from the starting place. This place mentions the first street (idx-I = 1), and the 0th loop. The green duration is assumed to be 10 seconds mark. After the ignition, the sign goes to the brain of the graphic as seen in Figure 4.

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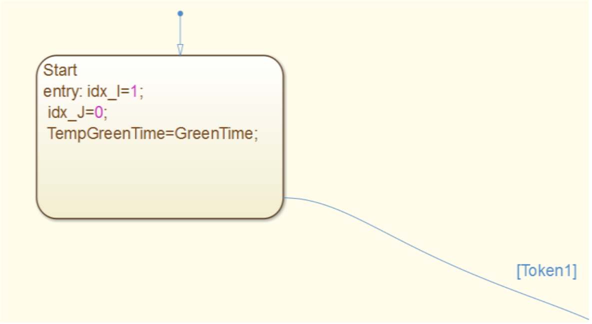

Figure 4. Initialization of the Petri net.

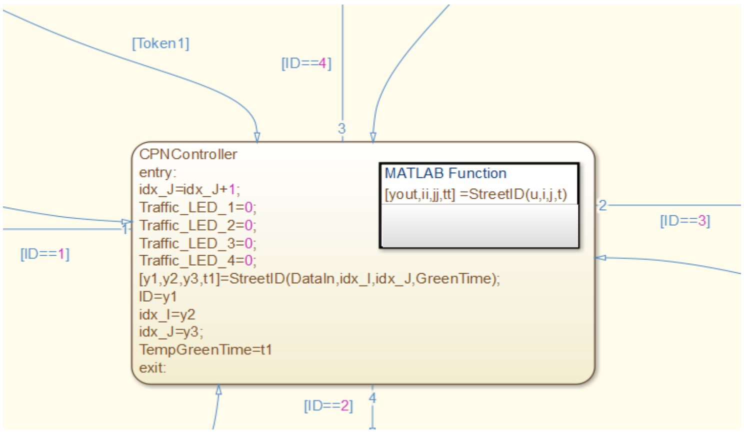

Figure 5. Traffic control brain part

The system starts the first loop after the control part created in the MATLAB program indicates the control part in Figure 5. First of all, the whole street glows red. Within the function in Figure 5, the number of cars on 4 streets with the descend tool in MATLAB are listed in descending order. Therefore, the cycle starts from the busiest street and ends at the least dense. The green time was calculated by the above function tt. Within this function, the number of cars on the street where the loop is located is divided by the number of cars of the busiest street and multiplied by the previously determined green time. These processes are repeated for 20 cycles.

3. RESULTS and DISCUSSIONS *(SONUÇLAR ve TARTIŞMALAR)*

In this study, it was investigated which method is more efficient by evaluating the real data of 4-way health crossing with fuzzy logic, (classical) fixed time method and petri net method. Vehicle density and green light duration of traffic lights are determined as "performance parameters" in Petri net method. Based on these parameters, there have been functions produced in the petri dish method that correlates between input and output. As a result, the desired change in the burning times and burning sequences of the green lights applied to the system input and depending on different vehicle intensity was observed.

When we run the collected data with Petri Network controller, results as in Table 1-3 are obtained.

Table 1. First study, at 12:00 data obtained by the petri net method of the streets at the Sıhha intersection

Cycle number	1. Street	2. Street	3. Street	4. Street	The number of cars passing through the intersection	Total time (s)
1	1	1	5	13	21	21
2	13	12	11	4	40	34
3	0	3	4	8	22	22
4	10	13	1	8	31	28
5	15	13	14	9	45	38
6	11	15	22	14	37	32
7	16	12	27	19	35	31
8	30	14	25	29	42	36
9	29	24	21	34	41	35
10	32	36	29	28	45	38
11	30	27	43	31	40	34
12	34	38	38	37	51	42
13	38	46	48	34	45	38
14	51	45	43	47	51	40
15	45	54	57	53	51	40
16	49	56	64	54	45	38
17	55	56	64	61	48	40
18	65	67	64	59	51	42
19	65	72	67	71	51	42
20	78	70	77	74	51	42

Table 2. Second study, at 16:00 data obtained by the petri net method of the streets at the Sıhha intersection

Cycle number	1. Street	2. Street	3. Street	4. Street	The number of cars passing through the intersection	Total time (s)
1	1	1	5	13	30	27,25
2	13	12	11	4	30	37,25
3	0	3	4	8	44	24,46
4	10	13	1	8	26	27,81
5	15	13	14	9	31	31
6	11	15	22	14	35	34,57
7	16	12	27	19	40	25
8	30	14	25	29	27	32,42
9	29	24	21	34	37	26
10	32	36	29	28	28	30,28
11	30	27	43	31	34	40,28
12	34	38	38	37	48	26,71
13	38	46	48	34	29	36
14	51	45	43	47	42	33,14
15	45	54	57	53	38	29,33
16	49	56	64	54	33	35,23
17	55	56	64	61	41	29,57
18	65	67	64	59	33	32,67
19	65	72	67	71	38	33,5
20	78	70	77	74	39	32

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Table 3.Third study, at 20:00 data obtained by the petri net method of the streets at the Sıhha intersection.

Cycle number	1. Street	2. Street	3. Street	4. Street	The number of cars passing through the intersection	Total time (s)
1	6	14	8	8	44	37,42
2	2	14	3	6	30	27
3	14	10	8	10	47	39,33
4	10	18	10	8	27	25,28
5	10	19	5	9	22	21,45
6	9	13	15	15	40	34
7	12	23	15	20	35	31
8	19	13	18	17	22	21,72
9	19	17	21	19	43	36,67
10	26	31	24	25	43	36,72
11	24	34	32	37	38	32,67
12	36	38	30	35	28	26
13	43	42	32	39	51	42
14	40	43	32	52	23	22,15
15	52	48	38	54	39	33,5
16	49	51	45	52	30	27,43
17	56	54	47	58	35	30,55
18	60	54	57	58	45	38
19	58	61	55	60	26	24,57
20	56	62	56	58	2	8

Table 4-6 I give the results obtained with the classical (definite time) controller.

Table 4.First study, data obtained by the classical method of the streets at the Sıhha intersection at 12:00

Cycle number	1. Street	2. Street	3. Street	4. Street	The number of cars passing through the intersection	Total time (s)
1	1	1	5	13	20	46
2	13	12	11	4	38	46
3	0	1	3	4	8	46
4	10	13	1	8	23	46
5	12	19	13	9	25	46
6	12	19	20	8	22	46
7	11	14	29	12	20	46
8	20	10	37	21	16	46
9	21	15	33	27	16	46
10	23	23	37	27	14	46
11	20	20	48	27	15	46
12	20	27	51	30	17	46
13	20	37	60	25	16	46
14	29	38	57	34	15	46
15	28	43	68	39	13	46
16	29	45	77	39	14	46
17	32	44	81	43	12	46
18	39	52	84	40	13	46
19	38	58	86	49	12	46
20	48	59	93	52	12	46

Table 5.Second study, data obtained by the classical method of the streets at the Sıhha intersection at 16:00

Cycle number	1. Street	2. Street	3. Street	4. Street	The number of cars passing through the intersection	Total time (s)
1	1	8	0	8	17	46
2	6	6	5	8	25	46
3	0	1	13	10	17	46
4	11	0	13	7	21	46
5	13	7	14	1	20	46
6	9	5	15	6	24	46
7	12	5	13	0	16	46
8	14	4	22	11	18	46
9	20	2	32	7	16	46
10	22	5	35	17	17	46
11	30	11	45	24	17	46
12	31	10	47	34	15	46
13	32	16	49	37	13	46
14	36	19	49	36	13	46
15	36	22	48	35	12	46
16	46	21	57	43	13	46
17	50	20	63	54	13	46
18	50	26	66	56	12	46
19	53	27	75	64	13	46
20	60	31	79	62	12	46

Table 6.Third study, data obtained by the classical method of the streets at the Sıhha intersection at 20:00

Cycle number	1. Street	2. Street	3. Street	4. Street	The number of cars passing through the intersection	Total time (s)
1	6	14	8	8	36	46
2	2	10	3	6	21	46
3	12	10	8	10	34	46
4	11	15	2	5	23	46
5	8	18	0	1	16	46
6	4	19	10	6	22	46
7	3	27	13	9	19	46
8	7	21	11	5	20	46
9	8	20	12	6	20	46
10	14	29	16	10	18	46
11	11	35	19	18	17	46
12	19	38	15	18	17	46
13	25	44	12	20	16	46
14	23	46	8	29	16	46
15	31	47	10	35	16	46
16	29	45	13	35	13	46
17	35	47	12	42	13	46
18	39	44	19	43	13	46
19	37	48	16	44	12	46
20	34	50	14	41	14	46

4. CONCLUSION *(DEĞERLENDİRME)*

In this article, traffic signaling control has been carried out with petri nets and classical methods. A comparison was made between traffic control with petri nets and traffic control with fuzzy logic. In Table 7, the comparison of 2 different methods in terms of the number of cars and time is given.

Table 7. Comparison of results

	Classical (fixed time)	**Petri Nets**
Total number of cars passed in the first study	341	849
Total duration of the first study (sn)	920	755
Total number of cars passed in the second study	286	741
Total duration of the second study (sn)	920	658
Total number of cars passed in the third study	376	696
Total duration of the third study (sn)	920	620

As seen in Table 7, while 849 cars pass in 755 seconds in the Petri network method, the total number of cars exiting the intersection in 920 seconds in the classical method is 341. In addition, when the petri nets were examined within the other hours, in the second study, the petri nets gave the best result with 741 passing vehicles for 658 seconds, and in the 3 studies, the simulation performed with petri nets again, with 696 vehicles passing, 620 seconds. It has been observed that the data obtained with the Petri controller is more advantageous both in terms of economy and time.

CONFLICT OF INTEREST STATEMENT *(ÇIKAR ÇATIŞMASI BEYANI)*

No potential conflict of interest was reported by the authors.

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