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Toward sustainable mobility in streets, problems and solutions-case study Tangier-

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Abstract*: Microscopic analysis concerns the moderate-sized systems where the number of transport units passing through the system is relatively small and there is a need to study the behavior of individual units in the system. The time headway has fundamental importance in traffic engineering, and is a significant traffic flow parameter, which have important applications in capacity estimation, Level Of Service (LOS), safety analysis, car following in highways and freeways. In this paper, the vehicle and pedestrian flow are investigated for an urban lane. We analyze the pedestrian crossing and vehicles congestion, the trajectory data used in this study was provided for an urban section in Tangier (Morocco).

Keywords— Trafic flow,* sustainable urban mobility, *decision tree,Ethnography, Qualitative research

I. INTRODUCTION

Cities suffer most from congestion, poor air quality and noise exposure (The city traffic generates 80% of the noise), urban transport is responsible for about a quarter of CO2 emissions from transport, and 69% of road accidents occur in cities. Apart from the consequences of the emission of gases into the environment, transport generates another set adverse effects on the lives of people [1],[2].
The design of streets and its planning is one of the fundamental bases of sustainable development in the field of mobility. In our work we have based on previous studies related to shared spaces and pedestrian traffic study according to the HCM 2010, also in previous studies have tried to study shared spaces from many approaches, analysing surveys and by applying statistical methods [3],[4],[5] .

In this paper we will analyze the mobility in part of Tangier city, Mexico avenue ,by studying the effect of interaction between pedestrian and private car. The methodology is based on data collection that relate to the daily mobility of the pedestrian and vehicles [2],[6],[7] ,the time headway between vehicles that affects the safety, level of service and pedestrian crossing [8],[9],[10] First we are going to make a collection of data related to the pedestrian traffic and vehicles, and according to these data we give some alternatives to solve the traffic congestion analyzing surveys conducted in the area of study, using the decision tree, to choose the solution most voted(by trained interviewers). We will also use qualitative research techniques 'Ethnography', observing behavior of pedestrians in front of the congestion also the behavior of drivers, which will help to reach the optimal solution [11],[12],[13].

II. PRESENTATION OF THE STUDY AREA

Tangier is located on the north African coast and at the western entrance to the strait of Gibraltar, during the last decade, it knows urban sprawl, the condensation of services and populations at several levels of size and distances. This concentration entails difficulties of transportation and parking, stress associated with displacements, noise, lack of space.
The study area, as depicted in figure 1 and 2, is located in the center of the city. More than 85 stores and 14 shopping centers, then it is a catchment area with high pedestrian movement. There is also a congestion of traffic at peak hours, with parking problems because of the lack free parking, even if there are 2 public parking in the area, but with little demand for use. The width of the street is very small 7 meter that causes poor circulation and congestion in the street intersections.

Figure 1 Study area

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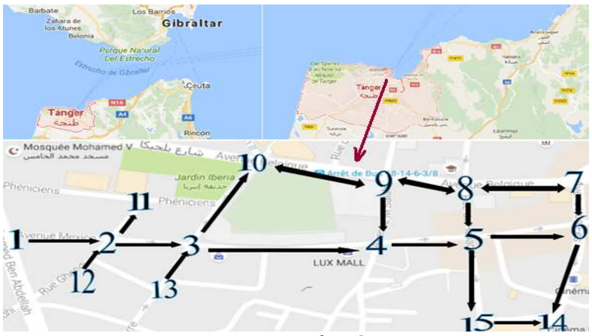

Figure 2 Location of study area

III. METHODOLOGICAL APPROACH

The methodology is based on the collection of data related to mobility, cars flow and pedestrian flow [6],[14]. To facilitate the work:

- We divided the study area into segments.
- We analyse each segment in relation to the pedestrian and vehicle mobility.
- We use qualitative research techniques, semi-structured surveys, and direct observation of behavior of users, both pedestrians and drivers.

A. Data collection

1- Digitalization of the road

The process of digitalization is done by modeling the road as a directed graph where the vertex correspond to the intersection and arcs are the street sections, as shown in figure 2 and 3. The digitization divides the study area into zones that should be manageable for on-site work.

Figure 3 Digitalization of the road

2- Pedestrian flow

The pedestrian mode is an important component of urban network, and affects the performance of sidewalks and crosswalks, as well as the entire network traffic operations by interacting with other traffic modes (vehicles). The HCM 2010 , provides several methodologies for evaluating the pedestrian Level Of Service (LOS) [12],[15].

We will study the pedestrian mobility by calculating the flow of pedestrians during 5 min in different point of the street in peak hours and the calculation interval is 30 min.

In our analysis, we use some techniques related to traffic Engineering [3].

It is necessary to divide it up into manageable segments as illustrated in figure 4,5,6, and 7. In order to make the results easier to interpret the Level Of Service (LOS) concept is used :

Section 1: Between nodes, 1 and 3

Figure 4 Pedestrian trajectory(1→3 and 3→1)

wide sidewalk (1→3) : 2,5m
wide sidewalk (3→1) : 6m
Street length: 130 m
Table I shows the result of our measures between nodes 1 and 3

TABLE I
MIDLEVEL FLOW AND SERVICE FOR SECTION 1

Start	**End**	**Average flow**	**Level of service(LOS) (ped/min/m2)**
1	3	7.82	B
3	1	4,76	A

Section 2: Between nodes, 3 and 4

Figure 5 Pedestrian trajectory(3→4 and 4→3)

wide sidewalk (3→4) : 7,5m
wide sidewalk (4→3) : 7,5m
Street length: 240 m
Table II shows the result of our measures between nodes 3 and 4

TABLE II
MIDLEVEL FLOW AND SERVICE FOR SECTION 2

Start	**End**	**Average flow**	**Level of service(LOS) (ped/min/m2)**
3	4	29	C
4	3	21,2	B

Section 3: Between nodes, 4 and 5

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Figure 6 Pedestrian trajectory(4→5 and 5→4)

wide sidewalk (4→5) : 7m
wide sidewalk (5→4) : 7m
Street length: 130 m
Table III shows the result of our measures between nodes 4 and 5

TABLE III
MIDLEVEL FLOW AND SERVICE FOR SECTION 3

Start	End	Average flow	Level of service(LOS) (ped/min/m2)
4	5	36,4	D
5	4	32,2	C

<u>Section 4:Between nodes, 5 and 6</u>

Figure 7 Pedestrian trajectory(5→6 and 6→5)

wide sidewalk (5→6) : 4m
wide sidewalk (6→5) : 4m
Street length: 156 m
Table IV shows the result of our measures between nodes 5 and 6

TABLE IV
MIDLEVEL FLOW AND SERVICE FOR SECTION 3

Start	End	Average flow	Level of service(LOS) (ped/min/m2)
5	6	37,5	D
6	5	42	D

Once the LOS was determined for each section, we proceed by analyzing percentages according to table 1.
As we can remark in figure 8 , type D LOS dominate for pedestrian movement, this is due to the level of attraction on avenue (shops, offices ..). Also the pedestrian mobility is higher in times 6 to 10 p.m.
Another resulting characteristic is the high level of pedestrian flow at the end of the day, as shown in figure 9.

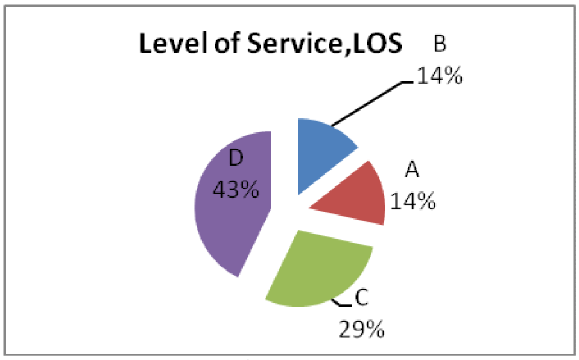

Figure 8 Level of service total in the avenue

At this level, we have characterized the flow of pedestrian mobility, and the next step will be the study of the microscopic flow, in particular the time headway.

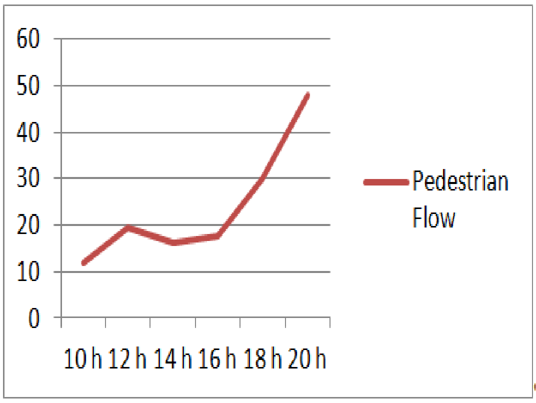

Figure 9 Hourly pedestrian flow

3- *Car Flow*

The traffic intensity measures the number of vehicles circulating in the streets [16],[17]. Divers mechanism are used to carry out this task, we choose traffic counter NC 300, as illustrated in figure 10

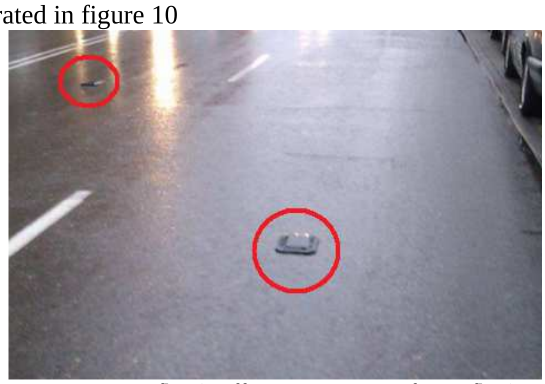
Figure 10 Car flow(Traffic counter NC 300 for car flow)

- Microscopic flow

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Microscopic analysis is selected for moderate-sized systems where the number of transport units passing through the system is relatively small and there is the need to study the behavior of individual units in the system. The time headway (as illustrated in Table V), is the time interval between 2 vehicles passing a point as measured from the front bumper to the front bumper [18],[1]

The mean time headway is Eq. 1 :

$$\bar{t} = \frac{3600}{V} \quad , \quad (1)$$ Where V, is vehicle flow rate

Table V recapitulates the overall characteristic of cars mobility. Column one indicates the time interval for data collection, the second column correspond to the traffic flow(veh/hr) in this time interval, the third column indicate the density(veh/km), and the last column indicate the time headway [19],[20].

TABLE V
MIDLEVEL FLOW AND SERVICE FOR SECTION 3

Time interval	**Traffic flow(veh /hr)**	**Density* (veh/km)**	**Time headway(mean)**
10:00 to 10:15	75	25	2,4
12:00 to 12:15	113	33	1,6
14:00 to 14:15	65	27	2,78
16:00 to 16:15	83	37	2,17
18:00 to 18:15	123	55	1,46
20:00 to 20:15	143	78	1,25

After calculating the value of time headway for each time slot all the day, we note that the value of time headway decreases, between time slot 6 to 8 p.m, and we can evaluate the variation of vehicle flow all the day as depicted in figure 11 Also, at this time there is a high pedestrian occupancy (LOS = D), so there is high congestion in both, vehicles and pedestrians.

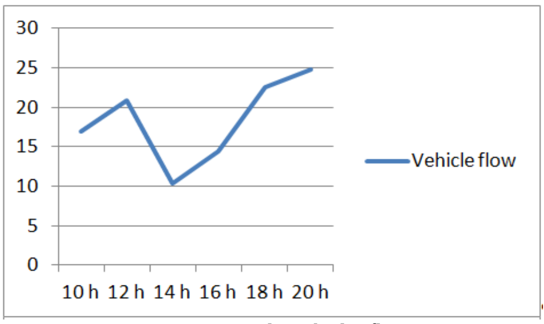

Figure 11 Hourly Vehicles flow

A shared space diverges from a conventional road where all road users are encouraged to legitimately occupy the same road space with little physical separation and the design aims to reduce the dominance of the vehicle [21]

we have to find a compromise on the coexistence of pedestrians and vehicles, we propose a method to locate the optimal solution to satisfy both pedestrians and the users of vehicles[22],[23],[24].

IV. DISCUSSION

In Mexico street, we have a group of actors, each group with its objectives, identifying the actors as, residents, administration and external users. On the other hand the objectives are: more parking spaces, protect environment, reduce congestion, job creation and improved aesthetics for the region..According to the table VI , the objectives most relevant are: to protect the environment and reduce traffic congestion [25].

TABLE VI
GROUP OF ACTORS AND OBJECTIVES

Objectives / Actors	More Parking	Protect environment	Reduce congestion	Job creation	Improved aesthetics for the region
Residents		X	X		X
Administration		X	X	X	X
External	X	X	X		

We have chosen alternatives, such as solutions to apply and with the help of surveys we will choose the most appropriate solution [26].

Alternatives could be:

1- Cancel the traffic for vehicles.

2- Temporary traffic reduction.

3- Expanding space for pedestrians and prohibited parking.

Now to choose the best alternative(solution) to find a commitment between all actors, we use the Decision Tree measure, and Ethnography as a qualitative methodology.

A- Selection criteria (Ethnography and Decision Tree)

We will carry out a description with the aim of recording relevant human facts of societal analysis, using Ethnography [27] this is a qualitative methodology, that use techniques, such as direct observation, semi-structured interview and oral communication. The individual interview is the most used and it was adopted in this study to achieve at more favorable results. We use a probabilistic approach of Eq (2) to select a representative sample of population to carry out our study .

The objective is to reduce the congestion inside the avenue and leave more space for pedestrians, we have decided to use

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the Decision Tree [28] by conducting surveys in the study area, to choose the best alternative as represented in figure 13. In step 1, we conduct a survey in the study area and is based on a population sample of n=40, using the following formula

$$n = \frac{N.Z^2_{\alpha}.p.q}{e^2(N-1)+Z^2_{\alpha}.p.q}; \qquad (2)$$

With,

- n, population sample
- N, population studied(In that case N=500), [18]
- Z^2_{α}, coefficient for a confidence level $1-\alpha$
- e, Estimation error
- p, Probability in favor (In that case p=0,5)
- q, Probability against(q=1-p).

This population is composed by, drivers, pedestrians and shopkeepers, after a statistical study of alternatives we proposed in our survey, percentages which are distributed as follows(Fig.13) :

- 40 % have opted for the second alternative, 'Temporary traffic reduction'.
- 35% have chosen the third alternative, 'Expanding space for pedestrians and prohibited parking' .
- 25% in favor of 'Cancel the traffic for vehicles'.

It must take into consideration that there are 3 alternatives with 4 attributes it must satisfy:

- Pedestrians, vehicles, cost and pollution levels.

It is necessary to leave more space for pedestrians, decrease traffic congestion (healthy environment) and carry out this work with a reasonable cost.

According to the collected data:

1- We can eliminate the first alternative, 25 % (the lowest percentage), this option solves the traffic congestion within the street but it does not take into consideration the surrounding streets.
2- The third alternative 'Expanding space for pedestrians and prohibited parking', this option will instead give more space for pedestrians less space for vehicles, but we will not solve the problem of congestion during peak hours, moreover environmental pollution will not change also the high cost of implementation.
3- We chose the second alternative (45%), 'Temporary traffic reduction'.
   Why we have to choose this option, and how we are going to implement it?
   a -Between the nodes 4 and 6, LOS=D, so we have high level pedestrian occupancy(Table IV).
   b -The pedestrian flow increases at the end of the day(Fig.9).
   c -The car occupancy rate(densities veh/Km) in a time interval 6 to 8 p.m is higher than other intervals(table V, fig.11).

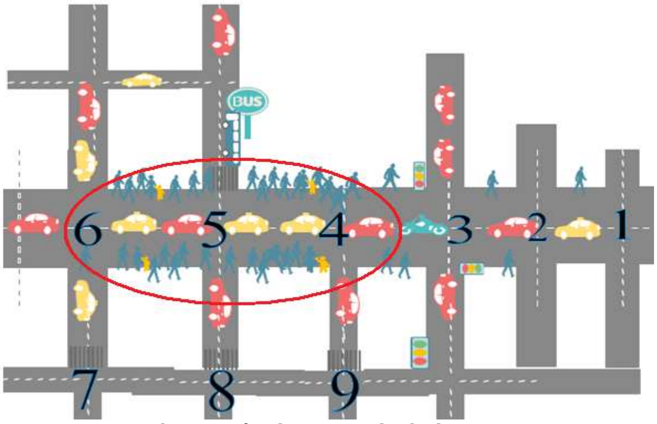

Figure 12 Distributions of pedestrians and vehicles in Mexico Avenue

So according with this data, pedestrians and vehicles occupy the same site(4→6) at the same time(5 to 10 p.m) with a high occupancy rate(Fig.12).

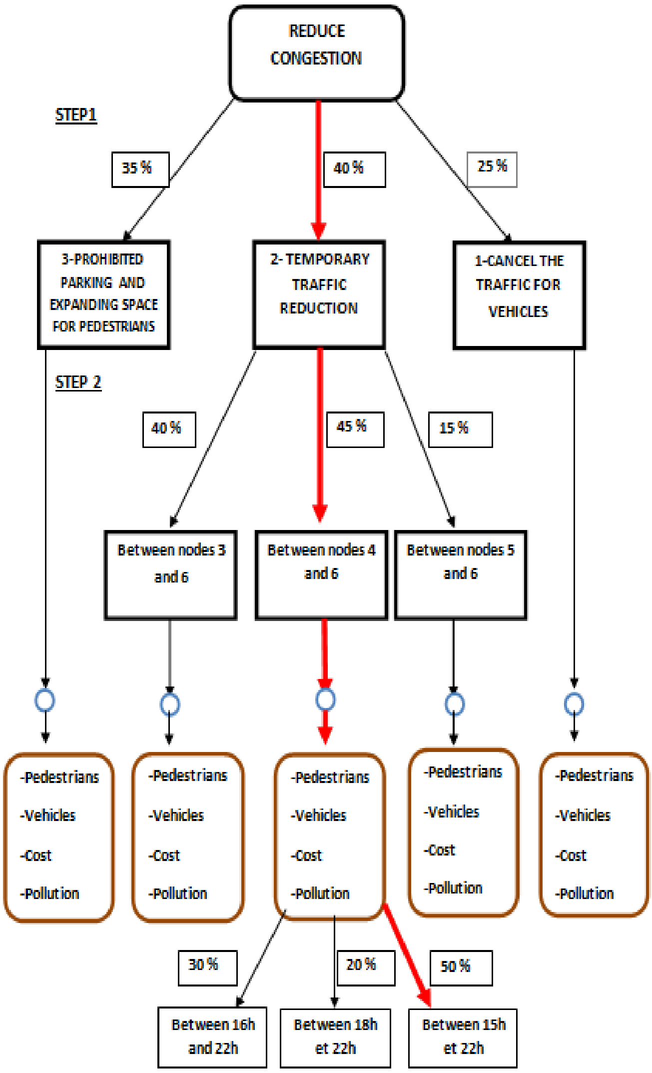

Figure 13 Decision Tree

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The consequences of implementation:

1- The vehicles flow between nodes 4 and 6(Fig.12), is the accumulation of flow 9→4, 3→4 and 8→5.
2- The vehicle flow 9→4 is the lowest throughout the week compared to 3→4 and 8→5 (Fig.14).
3- In 1 hour and 30 min of measurement (from 6:00 to 7:30 p.m.),
   -340 vehicles pass by the way 8→5,
      -100 of these vehicles pass by the way 5→6
      -240 vehicles by the way 5→15.

   So in terms of percentage, 29.41% use the road 5→6 and 70.59% use 5→15, so the majority of vehicles using the road that lead to 8→15 (Fez avenue, depending on the graph is the path of the node 7 in the direction of the node 6).
4- We can check the flow that circulates between nodes 4 and 5: according to the collected data (1 hour and 30 min of measurement), there are a total of :
      - 200 vehicles moving between these two nodes.
         - 80 vehicles pass between the nodes 5 and 6(in terms of percentage 40%).
         - 120 vehicles between nodes 5 and 14(60%). We observe that the path 8→15 is more used than 4→6.

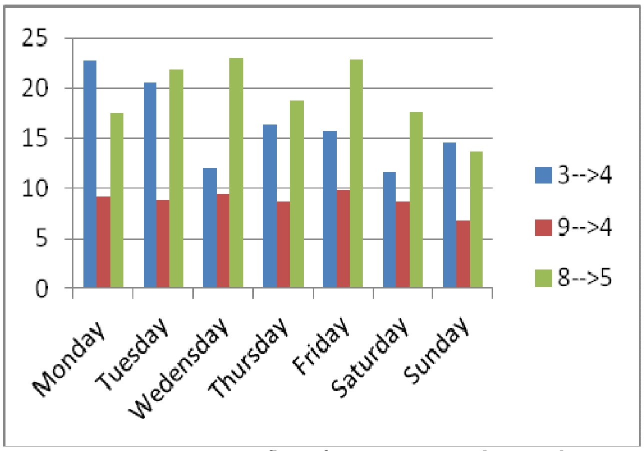

Figure 14 Average flow of cars per street and per week

Now according to these data, the most effective and optimal solution is temporarily close the avenue between nodes 4 and 6 and we can reverse the flow 9→4 as a flow 4→9 to facilitate the exit of vehicles that come from 3→4 and also facilitate access to park between nodes 3 and 4. We will not forget the consequences in terms of environmental contamination that will decrease significantly and also the acoustic contamination. The area will be completely occupied by pedestrians and also the closure of the avenue will not affect road traffic (4 hours of closing on 24h) the result will be (Fig 15).

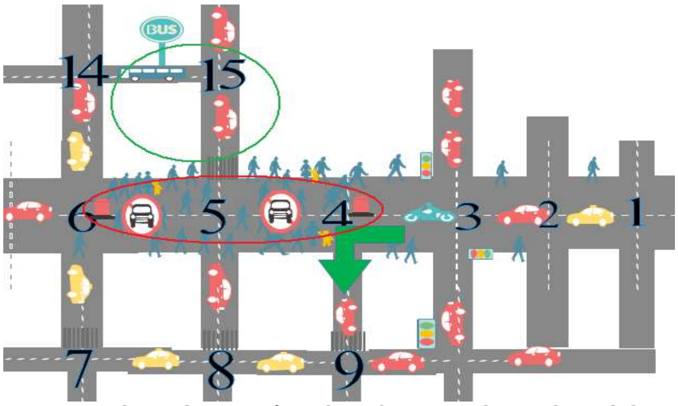

Figure 15 Change direction of circulation between nodes 9 and 4, and also change the bus station

Now, how to close temporarily the avenue?
There are two ways to do, manually or automatically:
We chose to do it automatically with the help of two automatic barriers, each on one side of the street, at fixed times between 6 and 10 p.m(Fig. 16) leaving all the space in that time range for pedestrians.


Figure 16 Automatic barriers

So we can add another solution that will further reduce traffic congestion (between nodes 5 and 15), that is to change the bus stop between nodes 5 and 15 and move it between nodes 15 and 14, in this way will not be formed queue of cars behind the bus (Fig. 15,16).
We have observed that there are many warehouses and shopping centers, which have vans for the loading/unloading of goods that cause a great deal of congestion and waiting queues because there are no reserved places. Since we propose to reserve a site for loading/unloading according to a fixed schedule that must be regulated by the administration.

V. Conclusion

In this article we studied the mobility in a region of great pedestrian movement, also the existence of vehicles causes serious problems of traffic. We have followed a methodology based on taking data related to pedestrian and vehicular traffic and we have also studied the flow of cars in the different streets, to see if the solution adopted will cause problems of

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traffic circulation. Analyzing this data in order to reach a compromise between pedestrians and the circulation of cars, we have been involved in direct surveys, find out alternatives or scenarios, to choose the optimal solution, using the decision tree and ethnography. At the end of the analysis we have reached a solution:

1- We can close temporarily with two automatic barriers within a fixed time slot (from 6 to 10 p.m), leaving all the space in that time range for pedestrians.
2- Change the location of the bus stop, as we can see in figure 16.
3- Reserve a site for loading/unloading of goods according to a fixed schedule that must be regulated by the administration.

All these solutions are going to radically change the mobility within the avenue, as well as the management of the avenue through automatic barriers, it's a new approach at the national level and is a new step toward the smart city.

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