Journal of the Eastern Asia Society for Transportation Studies, Vol.8, 2009

Manpower Demand Evaluation Model for Traffic Control Duties At Urban Intersections

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Abstract: Conducting traffic control duties at urban intersections significantly affects the operating efficiency of traffic in peak hours. How to make a good personnel allocation plan is a very important issue for urban traffic management. Therefore, this study constructed a manpower demand evaluation model of three objectives and nine criteria based on two-stage questionnaire surveys. The relative weight of the criteria was determined by the analytic hierarchy process (AHP). The generalized score of this evaluation model can be used to measure the need of traffic control manpower for urban intersections. According to this generalized score and a practical rule-of-thumb, this study proposed the personnel allocation principles further. Finally, this study found that the proposed model and principles are feasible by applying to two cases of the Taipei Police Districts.

Key words: *Urban intersections, Traffic conduct duty, Traffic control, Personnel.*

1. INTROUUCTION

Traffic control duties at urban intersections significantly affect the operating efficiency of traffic. Especially during the peak hours, conducting traffic control duties well could enhance the performance of operation instantaneously and help the citizens obeying the traffic code. (Tseng and Lin, 2001) In order to keep the intersections clear and avoid jams, the Taipei City Government has been assigning traffic policemen, administrative policemen, volunteer traffic guards (referred to as “volunteers”), and reserve traffic assistants (referred to as “reserve assistants”) to major road intersections to perform traffic duties during peak-hours in both the morning and the evening. However, there is no practical and scientific method to evaluate the demand of traffic-control manpower and no basic principles for personnel allocation. To allocate the limited manpower to the intersections as far as possible is what the police department can do. Therefore, the personnel allocation of traffic control duties can not be effectively implemented presently.

All main tasks of traffic policemen include traffic enforcement, accident investigations, road patrol and traffic control (Tsai, 1997; Tseng, 1998). In-depth understanding of police work and their duties is very helpful for reviewing personnel allocation and organization configuration (Tseng, 1998). The Department of Transportation, U.S. Federal Highway Administration commissioned the Northwest University to study the personnel allocations for various police units (DOT, 1991; 1993a; 1993b). The problems of traffic police manpower allocation (Tseng, 1998) and the police manpower required for traffic accident settlement (Tseng, *et al.*, 2001) has been discussed in Taiwan. Due to the inability of peak-hour signal controls to handle the complex and excessive vehicle flow, and to avoid catastrophic intersection congestion, traffic police are usually dispatched as much as possible to try and

keep the traffic in the intersections moving. However, there is no proper analysis method to rationally evaluate the personnel required and where to allocate them to.

In view of this, this study constructed a manpower demand evaluation model by a questionnaire survey plan of traffic police to investigate the functions of the traffic control duties and the needs of the manpower in Taipei. Based on the evaluation model, this study also proposed the personnel allocation principles. Furthermore, this study employed and tested the model and principles to two empirical cases in Taipei Police Districts.

2. TRAFFIC CONTROL DUTIES AT INTERSECTIONS

2.1 Basic description

In Taipei City, the intersection traffic control duties are carried out by four kinds of executors. They are the traffic policemen from the Traffic Division of Taipei City Police Department, the administrative policemen, volunteers from various Police Districts, and the reserve assistants from National Police Administration. Their duties are showed as follows:

(1) The main tasks of the traffic policemen include traffic enforcement, accident investigation, road patrol and traffic control (Tsai, 1997; Tseng, 1998). They have the highest professional traffic control abilities and can carry out the duties of traffic control at intersections with heavy traffic or at complex intersections better.
(2) The main tasks of the administrative policemen are generalized security and administration services. Traffic control duty during peak hours is a difficult task for administrative policemen and their abilities are lower than that of traffic policemen.
(3) Volunteers are selected and trained by the Police Districts to assist in maintaining orderly traffic flows during peak hours. Most of them were once taxi drivers. Their traffic control abilities vary greatly.
(4) Reserve assistants are young men that served as reservists in the military. They are selected and trained by the National Police Administration to work as traffic assistants (Tseng, *et al*, 2003). They usually do not have any field experiences and have low traffic control skills.

In Taipei, a total of 324 locations require traffic control during the morning peak hours. The personnel allocation for these duties includes 74 traffic policemen, 104 administrative policemen, and 224 volunteers. During the evening peak hours, a total of 316 locations require traffic control with 89 traffic policemen, 104 administrative policemen, and 218 volunteers.

The current personnel allocation for intersection traffic control in Taipei is shown in Table 1. Allocating one person per intersection is most common for 68.6% of the locations, even in the morning and evening peak hours. Table 1 shows the personnel allocation as follows.

(1) For the cases which one person was assigned, 54.7% of them were volunteers, 30.8% of them were administrative policeman, and 14.5% of them were traffic policeman.
(2) In the cases which two persons were assigned, 50.4% of them were one traffic policeman and one volunteer, 29.6% of them were one administrative policeman and one volunteer, 11.2% of them were two volunteers, and the rest.
(3) In the cases where three persons were assigned, 75.8% of them were three volunteers, 13.1% of them were one traffic policeman and two volunteers, 7.1% of them were one administrative policeman and two volunteers, and the rest.

Table 1 Manpower allocation for intersection traffic control duties in Taipei

No. of Manpower	Manpower allocation			No. of Intersections with Traffic Control Manpower		
	Traffic Police	Administrative Police	Volunteer	Morning	Afternoon	Total
1	1	0	0	34	37	71
	0	1	0	77	74	151
	0	0	1	146	122	268
2	1	1	0	1	2	3
	0	1	1	19	18	37
	1	0	1	27	36	63
	2	0	0	2	3	5
	0	2	0	1	2	3
	0	0	2	5	9	14
3	1	1	1	2	2	4
	1	0	2	6	7	13
	0	1	2	3	4	7
	0	0	3	1	74	75

2.2 Questionnaire Survey and Analysis

In order to investigate the factors of concern for traffic control duties at urban intersections, this study conducted a questionnaire survey. After asking the traffic police supervisors of Taipei Police Department, this study found the factors those supervisors cared for. There were 33 valid questionnaires and the details of which are shown in Table 2.

Table 2 Factors considered for planning intersection traffic control duties

Factors Considered	Statistics		
	Mean	Standard Deviation	Variation Coefficient
1. traffic flow	7.5	2.2	0.29
2. complexity of movements	8.8	1.3	0.15
3. pedestrian flow	6.5	1.5	0.23
4. difficulty of keeping clearance	7.8	2.1	0.28
5. road width	4.9	2.0	0.41
6. size of intersection	5.4	1.8	0.33
7. complexity of the geometric layout	7.3	1.7	0.24
8. adjacent to ramp	6.6	1.9	0.29
9. located on major road	6.6	2.0	0.31
10. adjacent to railway crossing	6.2	1.7	0.28
11. road under construction	6.7	1.8	0.27
12. w/wo contra-flow lane	7.2	2.1	0.29
13. no left-turn control	5.1	2.4	0.46
14. multi-phased signals	6.3	2.0	0.32
15. accident rate	6.1	1.7	0.29
16. traffic violation rate	6.7	2.1	0.32
17. adjacent to school	5.6	1.7	0.31
18. adjacent to traditional market	5.7	1.9	0.33
19. adjacent to shopping district	6.7	2.0	0.30
20. police visibility	4.0	1.9	0.48

Note: the data in this table is based on the scores of questions 1-10.

These twenty factors include traffic demand, geometric layout, traffic control, safety record, land use and other considerations. Among them, “complexity of movements” is the most important factor, while “difficulty to keep clearance”, “traffic flow”, “geometric complexity”, and “w/wo contra-flow lane” are also relatively important factors. In practice, the geometric complexity and the complexity of movements at urban intersections usually resulted in weaving conflicts and dangers. The heavy vehicle flow often resulted in keeping intersection clearance difficultly. The above mentioned factors are the key elements for choosing intersections to control prior. Besides, the complexity of traffic control is higher, more traffic control manpower are needed.

From the survey, this study also collected the efficacy of the traffic control duties. Table 3 illustrates the efficacy of the traffic control duties at intersections, and shows that those supervisors thought that “keep intersection clearance”, “monitoring traffic”, “keep traffic order” and “improve emergency handling efficiency” are the most efficient functions.

Besides, different traffic control personnel have different traffic control abilities. In order to understand the differences of traffic control ability and performance between various personnel, this study applied the AHP (Analytic Hierarchy Process, AHP) (Saaty, 1980) method to evaluating them. Using pair-wise comparison, the results are shown in Table 4. Traffic control abilities included traffic control actions, whistling and spirit. Traffic control performance means the ability to maintain a proper flow across an intersection with an appropriate vehicle discharge rate. Traffic police have the highest ability and the highest performance when it comes to carrying out traffic control duties.

Table 3 Functions of traffic control duties at an intersection

Scopes	Control Functions	Statistics		
		Mean	Standard Deviation	Variation Coefficient
Order	1. keep traffic order	7.7	1.3	0.17
	2. keep intersection clearance	8.4	1.8	0.21
	3. increase travel speed	6.1	1.7	0.28
	4. reduce vehicle delay	6.6	1.4	0.22
Safety	5. protect pedestrian safety	6.7	1.5	0.23
	6. reduce accident rate	6.3	1.9	0.31
Other	7. reduce violations by pedestrians	7.3	1.8	0.25
	8. monitor traffic	7.8	2.1	0.27
	9. improve emergency handling efficiency	7.7	2.1	0.27
	10. improve road users satisfaction	6.3	1.8	0.29

Table 4 Comparison of various personnel in terms of control ability and performance

Traffic Control Ability			Traffic Control Performance		
Personnel	Weight	Relative Weight	Personnel	Weight	Relative Weight
Traffic police	0.42	1.00	Traffic police	0.42	1.00
Volunteer	0.24	0.55	Administrative police	0.24	0.55
Administrative police	0.21	0.50	Volunteer	0.21	0.50
Reserve assistant	0.13	0.30	Reserve assistant	0.13	0.30

As shown in Table 4, in spite of the fact that the traffic control abilities of the volunteers are better than those of the administrative policemen in average, the control performances of administrative policemen are better than those of volunteers. This may be due to the fact that the administrative policemen dress in uniform and have the authority to limit vehicles and pedestrians when carrying out their traffic control duties.

Because reserve assistants have had little professional training, they maybe feel nervous and scared when faced with complex intersection control duties, and the fact that they have to control road users. Their control ability and performance are not good usually. Therefore, it is recommended that they not be assigned unless there is a serious shortage of manpower.

3. THE MANPOWER DEMAND EVALUATION MODEL

Based on above-mentioned characteristics from survey, the traffic conduct manpower evaluation model is proposed in this section.

3.1 Operation Process

The operation process of evaluating the intersection traffic-conduct manpower allocation is proposed as follows:

Step 1: Collect basic data of all intersections
Step 2: Analyze manpower demand by using evaluation model
Step 3: Allocate manpower according to demand evaluation score
Step 4: Calculate additional manpower response to special demand
Step 5: Determine final manpower allocation

3.2 Structure of Demand Evaluation Model

The evaluation structure of the manpower allocation demand is shown in Figure 1. It includes 3 objectives and 9 criteria, which are defined as shown in Table 5.

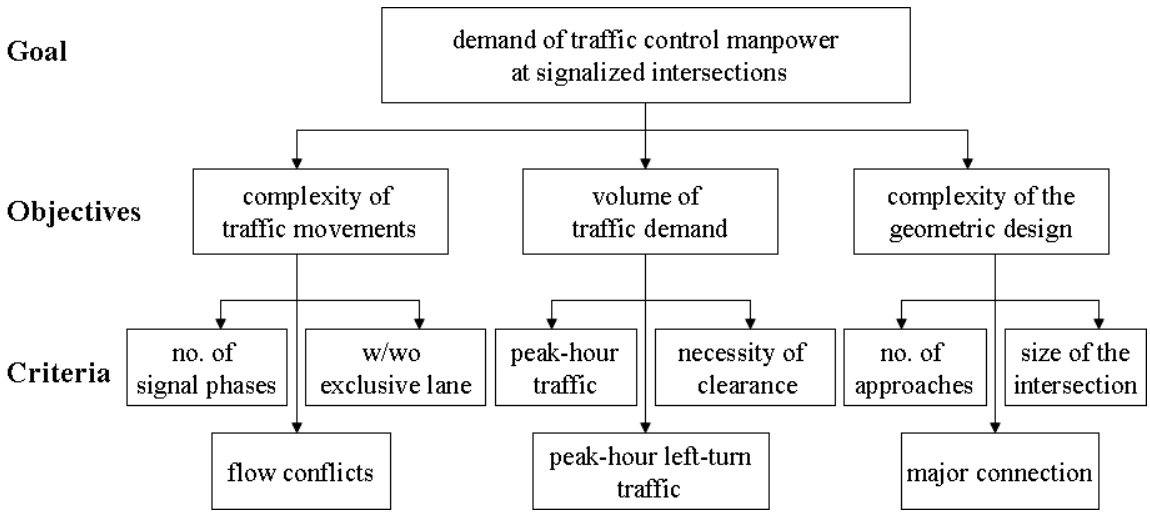

Figure 1 Evaluation structure of traffic control manpower demand at intersections

Table 5 Evaluation criteria of traffic control manpower demand at intersections

Objectives	Criteria	Measurement
Complexity of movements	C11: no. of signal phases	More signal phases implies a complexity of the movements of all approaches.
	C12: flow conflicts	If the traffic conflicts are more, there is more need for traffic control
	C13: w/wo exclusive lane	When there is an exclusive lane in the intersection approach, traffic control becomes more important.
Volume of traffic demand	C21: peak-hour traffic	Peak-hour traffic volume has a basic index for traffic demand.
	C22: peak-hour left-turn traffic	Left-turn vehicles have a significant influence on the operation of an intersection.
	C23: necessity of clearance	Some intersections are difficult to keep clearance for some reasons. They have higher necessity of clearance.
Complexity of the geometric design	C31: no. of approaches	The number of approaches increases the complexity of an intersection, especially the irregular geometric design of the intersection.
	C32: major connection	If the intersection is linked to an entrance or exit of a freeway or expressway, adjacent to a major bridge, then the traffic control duties become more important.
	C33: size of the intersection	The size of the intersection is related to the complexity of the layout.

3.3 Model Construction

3.3.1 Determination of the relative weights of the criteria

Moreover, this study employed an AHP questionnaire to obtain the opinions of 14 police officers, for determining the relative weight of the evaluation objectives and of the criteria as shown in Table 6. All officers had more than five years of supervisory experience at intersection traffic control duties. Table 6 shows that the relative weight of the “flow conflicts” is the highest (0.21), followed by “necessity of clearance” (0.19) and “peak-hour left-turn traffic” (0.12), while “Size of intersection” has the lowest relative weight (0.05).

Table 6 Relative weights of each criterion

Objectives	Weight	Criteria	Weight	Relative Weight(W_{jk})
O1:Complexity of movements	0.39	C11: no. of signal phases	0.29	0.11
		C12: flow conflicts	0.54	0.21
		C13: w/wo exclusive lane	0.17	0.07
O2:Volume of traffic demand	0.38	C21: peak-hour traffic	0.19	0.07
		C22: peak-hour left-turn traffic	0.32	0.12
		C23: necessity of clearance	0.49	0.19
O3:Complexity of the geometric design	0.23	C31: no. of approaches	0.47	0.11
		C32: major connection	0.30	0.07
		C33: size of the intersection	0.23	0.05
Sum	1.00	--	--	1.00

3.3.2 Grade of the criteria

As shown in Table 7, a Likert-type scale was used to measure the criteria scores. The measurements were obtained from in-depth interviews with five veteran traffic-police officers. In the four point scale, the higher number indicates that more traffic control manpower is required.

Table 7 Measure of the evaluation score of criteria

Objectives	Criteria	Measure of evaluation score			
		4	3	2	1
O1: Complexity of movements	C11	≧4	3	2	2 phase with no-left turn or no signal
	C12	no protected phase, left-turn vehicles usually conflict with the opposing vehicles	no protected phase, left-turn vehicles have a higher rate of conflict with opposing vehicles	no protected phase, left-turn vehicles have a lower conflict with the opposing vehicles	no obvious conflict in the traffic flow
	C13	with exclusive bus lane or motorcycle lane	--	--	no exclusive lane
O2: Volume of traffic demand	C21	≧ 8,000 pcph	7,999~6,500 pcph	6,499~5,000 pcph	< 4,999 pcph
	C22	≧ 1,600 pcph	1,599~1,000 pcph	999~700 pcph	< 699 pcph
	C23	very high necessity of clearance	high necessity of clearance	Light necessity of clearance	no obvious necessity of clearance
O3: Complexity of the geometric design	C31	≧5 approaches or a roundabout	irregular 4 approaches or 3 approaches intersection	regular cross intersection	regular T-type intersection
	C32	adjacent to the entrance or exit of a freeway or expressway, or a major bridge, or adjacent to a major bridge	--	--	none
	C33	intersection of two major arterial roads	intersection of major road and branch road	intersection of two branch roads	intersection with a one-way road

3.3.3 Measure of the manpower allocation demand

This study employed Equation 1 to calculate the personnel evaluation scores of the analyzed intersections to estimate the traffic control personnel required for an intersection. The higher scores represent the higher demand on the traffic control personnel.

$$S_i = \sum_{j=1}^{3} \sum_{k=1}^{3} C_{ijk} W_{jk} \tag{1}$$

where

i : the ith intersection, in a total of n intersections,

j : the jth evaluation objectives, in a total of 3 objectives,
k : the kth criteria,
S_i : the manpower evaluation score of the ith intersection,
W_{jk} : the weight of the jth evaluation objective and the kth criteria,
C_{ijk} : the evaluation score of the ith intersection on the jth objectives and the kth criteria.

Based on the results of the various criteria calculations, the scores of the evaluated intersections are categorized into A, B, C, D levels as shown in Table 8. According to checking the scores under various situations, this study define that the scores below 2.0 imply no needs of traffic control personnel, and the score larger than 3.0 imply to needs over 3 persons. The four categories mainly consider that 0~3 persons are usually allocated for intersection traffic control duty in Taipei. If the score of an intersection is high, then this means that the complexity of the intersection is high, and requires more traffic control manpower be assigned to it. In practice, in the case of an intersection with simple traffic features, traffic control personnel may not be needed at all.

Table 8 Recommended traffic control personnel at intersection

Level	Score (S_i)	Recommended Number of Personnel (N_a)
A	$S_i \geqq 3.0$	3
B	$2.5 \leqq S_i < 3.0$	2
C	$2.0 \leqq S_i < 2.5$	1
D	$S_i < 2.0$	0

3.3.4 Manpower allocation principle

Because a reserve assistant is not allowed to perform any traffic control duty alone, this study did not consider their assignments. According to the above analysis, this study proposed a combination of 1 to 3 persons for intersection traffic control duties as shown in Table 9, based on the evaluation score.

Table 9 Recommended traffic control personnel allocation at intersection

Level	Number of Personnel	Score (S_i)	Personnel Allocation	Code
A	3	$S_i \geqq 3.4$	1 traffic police 1 administrative police 1 volunteer	A-1
		$3.2 \leqq S_i < 3.4$	1 traffic police 2 volunteers	A-2
		$3.0 \leqq S_i < 3.2$	1 administrative police 2 volunteers	A-3
B	2	$2.9 \leqq S_i < 3.0$	1 traffic police 1 administrative police	B-1
		$2.7 \leqq S_i < 2.9$	1 traffic police 1 volunteer	B-2
		$2.5 \leqq S_i < 2.7$	1 administrative police 1 volunteer	B-3
C	1	$2.4 \leqq S_i < 2.5$	1 traffic police	C-1
		$2.2 \leqq S_i < 2.4$	1 administrative police	C-2
		$2.0 \leqq S_i < 2.2$	1 volunteer	C-3
D	0	$S_i < 2.0$	none	none

3.3.5. Adjustment by special conditions

The evaluation of the peak-hour intersection traffic control manpower requirement for some intersections with special characteristics such as having a contra-flow lane, mass rapid transit (MRT) construction or being adjacent to a railway crossing, usually need extra manpower to keep the traffic flowing. The allocation model proposed in this study takes these conditions into consideration and allows for an additional 0 to 2 personnel. Therefore, the personnel calculation method for the adjusted model is as follows.

$$N_i = N_{ia} + N_{ib} \tag{2}$$

where

N_i : total number of personnel allocated to the ith intersection,

N_{ia} : estimated number of personnel allocated to the ith intersection according to Equation 1 and Table 9,

N_{ib} : recommended number of additional personnel allocated to the ith intersection with special traffic characteristics, N_{ib} was 0, 1 or 2.

4. CASE STUDY

This study employed the analysis method to two empirical case studies, the Taipei Daan Police District (Case I) and the Chungcheng Second Police District (Case II).

4.1 Case I

The Daan Police District is located in Taipei downtown and the roads are laid out in a checkerboard style. These roads are the major access from Chonghe and Younhe to Taipei during the peak-hours, and carry heavy traffic. Most intersections are of a regular geometric design with a permitted left-turn phase or a forbidden left-turn, and flow conflicts are usually not serious.

The current number of intersections in the Daan Police District that has traffic control personnel allocated in the morning peak-hours is 27. According to the proposed evaluation model and the allocation principles (as shown in Table 9), the results of the analysis is shown in Table 10. One intersection allocated the A-3 type, 2 intersections allocated the B-2 type, 3 intersections allocated the B-3 type, 3 intersections allocated the C-1 type, 6 intersections allocated the C-2 type, 5 intersections allocated the C-3 type, and 7 intersections did not allocate any traffic control manpower. In addition, due to the MRT construction on Hsin-Yi Road, one additional volunteer was allocated to each of its six intersections.

The comparison of the current manpower allocation and the proposed allocation by the model shows that:

(1) Eight intersections had the same manpower demand and manpower allocation, 12 intersections had the same manpower demand but a slightly different manpower allocation, 7 intersections had different manpower demands, and 7 intersections were deemed by the application of the proposed model as not having any need for traffic control personnel.

(2) The current manpower allocation in some intersections was not adequate, such as assigning volunteers to high traffic control demand intersection or assigning administrative police and even traffic police to intersections with a lower traffic control demand. These inappropriate allocations also were the main reason for the differences in

traffic control quality in some intersections. However, generally speaking the manpower allocations were rational.

(3) The manpower for the current allocation was 3 traffic policemen, 11 administrative policemen and 22 volunteers, for a total personnel count of 36. After applying the model, it was found that the duties should increase two traffic policemen, reduce one administrative policeman and four volunteers.

(4) The analysis of the Daan Police District traffic control study revealed that 7 intersections did not need to have any traffic control personnel. And, the Daan Police District should shift the current personnel to strengthen the peak-hour patrols duties and traffic enforcement.

Table 10 Analysis of the results of Case I

No. of Intersection	Objective 1			Objective 2			Objective 3			Score	Suggested Manpower Allocation	Additional Manpower (N_b)
	C11	C12	C13	C21	C22	C23	C31	C32	C33			
1	4	1	1	4	4	4	3	4	4	3.07	A-3	0
2	3	3	1	3	2	4	3	1	4	2.79	B-2	0
3	4	1	4	3	4	3	2	1	4	2.74	B-2	0
4	4	1	1	3	2	4	2	4	4	2.65	B-3	0
5	4	1	4	3	1	3	2	4	4	2.53	B-3	0
6	3	3	1	4	1	3	2	1	4	2.51	B-3	0
7	1	3	1	4	1	4	2	1	4	2.47	C-1	0
8	3	1	4	3	3	3	2	1	4	2.45	C-1	1
9	3	1	4	4	2	3	2	1	4	2.41	C-1	0
10	3	1	1	4	4	1	3	4	4	2.39	C-2	0
11	4	1	1	4	3	3	2	1	3	2.39	C-2	0
12	1	1	4	3	2	4	2	1	4	2.30	C-2	1
13	2	1	1	4	1	3	3	4	4	2.29	C-2	1
14	3	3	1	4	1	1	2	4	3	2.28	C-2	0
15	4	1	4	4	3	1	2	1	4	2.26	C-2	0
16	3	2	1	3	1	3	2	1	3	2.17	C-3	0
17	2	3	4	3	1	1	2	1	4	2.14	C-3	0
18	2	1	4	3	1	3	2	1	4	2.10	C-3	0
19	3	1	1	4	3	1	3	1	4	2.06	C-3	0
20	2	2	1	2	1	2	2	4	3	2.01	C-3	0
21	3	1	4	3	1	1	3	1	4	1.94	none	0
22	3	1	4	3	1	1	2	1	4	1.84	none	0
23	3	1	4	3	1	1	2	1	4	1.84	none	1
24	2	1	4	3	1	1	2	1	4	1.72	none	1
25	3	1	1	3	1	2	1	1	4	1.72	none	0
26	1	2	4	2	1	1	2	1	3	1.70	none	1
27	2	1	1	3	1	1	2	1	3	1.47	none	0

4.2 Case II

The Chungcheng Second Police District is located in the Fraternity District where the Presidential Palace is located. It consists of a narrow strip of land with general urban traffic features. The district had two north-south roads, an expressway with heavy traffic, and three bridges linking the area with Banciao and Younhe. The major roads are laid out in a

checkerboard style, with some irregular geometric intersections. Because the size of the intersections is rather narrow, there are relatively more flow conflicts.

The current number of intersections that have traffic control personnel allocated for the morning peak-hours in Chungcheng Second Police District is 20. The number required according to the proposed evaluation model and allocation principles (shown as Table 9), are shown in Table 11.

One intersection was allocated the A-3 type, 1 intersection was allocated the B-1 type, 1 intersection was allocated the B-3 type, 1 intersection was allocated the C-1 type, 5 intersections were allocated the C-2 type, 6 intersections were allocated the C-3 type, and 5 intersections were not allocated any traffic control manpower. In addition, there were 6 intersections with special factors such as being adjacent to a school, one-way roads, exclusive bus lane and the presidential palace, that required 7 additional volunteers.

Table 11 Analysis results of Case II

No. of Intersection	Objective 1			Objective 2			Objective 3			Score	Suggested Manpower Allocation	Additional Manpower (N_b)
	C11	C12	C13	C21	C22	C23	C31	C32	C33			
1	4	1	1	4	4	4	4	4	4	3.17	A-3	0
2	3	2	1	4	4	4	3	1	4	2.95	B-1	0
3	4	1	4	4	3	2	3	1	4	2.56	B-3	0
4	3	2	1	3	1	3	3	4	2	2.43	C-1	0
5	3	1	1	1	2	4	3	1	2	2.18	C-2	0
6	2	1	1	2	4	2	3	4	4	2.32	C-2	1
7	2	3	1	2	3	2	2	1	4	2.30	C-2	0
8	3	2	1	1	1	3	4	1	4	2.29	C-2	0
9	3	2	1	1	1	2	3	4	4	2.21	C-2	0
10	4	2	1	1	1	2	4	1	3	2.16	C-3	0
11	2	2	1	1	1	4	1	4	1	2.10	C-3	0
12	3	1	4	2	1	2	3	1	4	2.06	C-3	0
13	2	1	1	1	1	4	2	4	2	2.05	C-3	0
14	3	1	1	4	1	1	3	4	4	2.03	C-3	0
15	3	1	4	4	1	1	3	1	4	2.02	C-3	0
16	3	1	1	1	1	3	3	1	1	1.82	none	1
17	3	1	1	1	1	1	3	1	4	1.60	none	2
18	2	1	1	1	1	1	3	1	4	1.49	none	1
19	1	1	1	2	1	1	2	1	4	1.34	none	1
20	2	1	1	1	1	1	1	1	1	1.11	none	1

The comparison of the current personnel allocation for case II and the allocation of proposed model shows that:

(1) There were 9 intersections with the same manpower requirements and allocation, 11 intersections had the same manpower demand but a slightly different manpower allocation. In spite there were 5 intersections deemed by the proposed model as having no need for any traffic control personnel, this study considered additional traffic control personnel (N_b) by adjustment factors.

(2) The manpower of current assignment was 2 traffic policemen, 8 administrative policemen and 15 volunteers, in a total of 25 personnel. By using the model, it is found that traffic

policemen should be reduced by 2 persons, administrative policemen should be increased by 2 persons and volunteers should be reduced by 1 person, and lead to a total reduction of 1 personnel.

4.3 Discussions

The empirical analysis of cases I and II showed that the proposed manpower demand evaluation model and allocation principles could be efficiently applied for police agencies in Taipei. However, the current empirical analysis is based on morning peak-hour scenarios. In fact, the characteristics of morning and evening traffic might be different, and possibly leading to different traffic control personnel demands and personnel allocation. If we take the Chunghsiao E. road and Dunhua S. road intersection in case I as an example, then we find that it was evaluated to be in need of one traffic police officer for the morning peak hours, and 1 traffic police officer and 1 volunteer for the evening peak hours due to the increased trips from the department stores. In other words, the different traffic features of morning and evening peak hours should be discussed individually, and our proposed model can reflect these traffic features. The personnel demand evaluation model proposed in this study is suitable for practical application.

5. CONCLUDING REMARK

Good traffic control duties can enhance the performance of intersection operation, and they are needed especially in peak hours. Through two-stage questionnaire surveys, this study established a traffic control personnel demand evaluation model and proposed personnel allocation principles to help intersections getting suitable personnel plans.

Firstly, this study investigated the key factors which the traffic police supervisors concerned about the manpower of traffic control duties at intersections. From the analysis of questionnaire surveys, this study found that the factors of concern include “complexity of movements”, “difficulty to keep clearance”, “traffic flow”, and “complexity of the geometry of the intersection”. Next, this study got the first four efficient functions of the traffic control duties at intersections based on those supervisors thinking. These functions include “keep intersection clearance”, “monitoring traffic”, “keep traffic order” and “improve emergency handling efficiency”. This study also found the relative ability ratios to carry out traffic control duties of traffic policemen, administrative policemen, volunteers, and reserve assistants are: 1.00: 0.50: 0.55: 0.30; respectively, and the performance ratios are: 1.00: 0.55: 0.50: 0.30, respectively. Finally, this study proposed the model and personnel allocation principles. Furthermore, two empirical cases analysis of Taipei Police Districts showed that the proposed model could determine the actual manpower requirements practically.

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