# Effect of Introducing Evacuation Route Flexibility and Demand Variations on Bus-Based Evacuation Planning

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The models devised for bus-based evacuations calculate the evacuation time required for complete evacuation with known input resources as well as to specify the routes for individual bus trips. The different techniques used to minimize the evacuation time target either to improve the demand side or the supply side of the mechanism. A great care must be observed to avoid negative impacts of such improvement factors, if any. In this study, two important factors; evacuation route flexibility and the demand variations are discussed with respect to their effects on optimality of the results found. The need for improvement in the objective function typically used for evacuation planning studies is also investigated. For this purpose, the model for short-notice bus-based evacuation under dynamic demand conditions (SBED model) is used to illustrate the evacuation planning for a small town Kawajma. The model was run by assuming different scenarios to simulate the stated issues. The results indicated a positive impact of introducing evacuation route flexibility in the model. In addition, suggestions to improve the objective function for a bus-based evacuation planning model are proposed at the end.

***Key Words :*** *Bus-Based Evacuations, Evacuation Route Flexibility, Demand Variations*

## 1. INTRODUCTION

The research in the field of outdoor evacuation planning has got boom in the aftermath of frequent natural and man-made disasters since the last couple of decades. Transportation planning is more complicated in case of disasters as the demand is quite uncertain and much higher than day-to-day level. A detailed transportation plan to meet such demands is based on the stage of disaster for which it is being prepared i.e. either to plan some activities involved in pre-disaster stage (infrastructure assessment, scenario analysis) or during disaster (traffic assessment, evacuation of people/goods, recovery actions) or at post-disaster stage (traffic management, network accessibility). The evacuation of people from danger area to the safe places is the top priority, whenever it is possible to do so. Thanks to the advancements in technology which made it possible to preempt some kinds of disaster like floods and hurricanes. The people of such areas can be shifted to safe places during the short notices available for such disasters.

The short-notice bus-based evacuation planning mainly consists of three basic steps: assessment of evacuees, decision about evacuation mode to be used and preparation and execution of a detailed evacuation plan based on model output[1)]. The people reported to suffer from such disasters belong to different classes of society[2,3)] with majority of victims as elderly[4)]. The choice of travel mode for evacuation depends on a number of factors like characteristics of the disaster, travel distance to safety, location of evacuees at the time of warning issued, and available options for evacuation[5)]. The two largest evacuations in the history of the United States, Katrina and Rita, are described as the most successful for the people with automobiles. However, public-transport dependent citizens could not be evacuated because of poor management[6)].

Studies in the literature present short-notice evacuation models with different optimized variables like travel times, traffic delays, arrival times, number of evacuees, and identification of evacuation routes[7)]. The basic output of a model for bus-based evacuation is bus evacuation route and the evacuation time with given number of buses. A simple model for bus dispatch was proposed in 2006[8)] to calculate the number of buses of known capacity performing trips on assigned routes, required to evacuate a known number of evacuees from pickup points to shelters of defined capacity within a given evacuation time. The model has limitations of fixed route assignment, single bus trips, and application to smaller areas. A topic quite similar to bus-based evacuation and fairly well studied in the literature is that of vehicle routing problems (VRP) [9)]. The difference lies in the objective of VRP which is to minimize the travel cost instead of travel time for evacuation, while fulfilling travel demand at different origins and destination nodes through a fleet of transit vehicles. A variant of VRP, bus evacuation problem (BEP) model[10)] has an objective to transport evacuees from pickup locations to shelters in a minimal amount of time by rerouting a fleet of homogeneous and capacitated buses located at one or more yards. In BEP model, demand for evacuation at pickup points were assumed to be fixed and known at the start of evacuation with all possible evacuation routes supposed to be specified.

In an extended version of BEP, called robust bus evacuation problem (RBEP)[11)], the evacuation conducted before knowing the exact number of evacuees is found to be better in terms of lesser evacuation time than that of conducted after knowing the number of evacuees. The concept of supply of evacuees at pickup points using a mobilization curve[13)] was employed in the model for no-notice evacuation of transit-dependent citizens (NETDC)[12)]. The model has several limitations like lacking of its ability to identify initial optimal assignment of transit vehicles to pickup points, and performinf single bus trip on specified evacuation routes. In a recent study by Asif-Nawaz et al[1)], a model has been proposed for the evacuation of areas prone to disasters with short-notice warnings, namely, a model for short-notice bus-based evacuation under dynamic demand (SBED model). The model can be employed to plan the evacuation of estimated total number of evacuees, arriving at pickup points following some defined arrival pattern, to shelters within a specified warning time using an available fleet of buses performing multiple trips with their flexible route option. The various techniques proposed to minimize the evacuation times include crossing elimination or lane based evacuation[14)], location of optimum service areas and vehicle routing[15)], and staged evacuation[16)]. Further, Murray-Tuite[5)] summarized measures on supply side like contraflow operations[17)], special signal timings[18, 19)] and shoulder lane use[20)]. The elimination of certain turning and crossing maneuvers at intersection is used to facilitate the traffic movement. This type of evacuation route without intersection provide continuous traffic flow and reduce accidents[21)]. Moreover, the specified evacuation route must be capable to account for demand inflation and supply deflation[22)]. On the other hand, introducing this route flexibility increases the computational time of the evacuation models and emphasizes the need for developing various algorithms[23)].

From the literature review, two main factors affecting the evacuation time come out to be the evacuation route and the demand variations. In this study we have used the SBED model to investigate in detail the effects of introducing evacuation route flexibility and demand variations on bus based evacuation planning. For this, various scenarios are analysed and imrovement in the objective function typically used in evacuation models is suggested. The remainder of this paper is organized as follows.

The remainder of this paper provides description of the SBED model used to elaborate the issues raised above in section 2. Section 3 presents a case study on evacuation planning of Kawajima Town, a town surrounded by rivers on both sides and prone to flooding, with results and discussion in section 4. Conclusions drawn from the case study results and further research options are described in the last section 5.

## 2. THE MODEL

We have used the SBED model based on the time–space network. For the detailed description about construction of time-space network diagram and its components along with the model details, readers may refer to the study by Asif et al[1)]. However, to get an idea, **Fig.1(a)** showing a sample road network and **Fig.1(b)** explaining the transformed T–S network diagram with nodes and arcs for each road are reproduced here.

A mixed integer linear programming formulation of SBED model uses two decision variables:

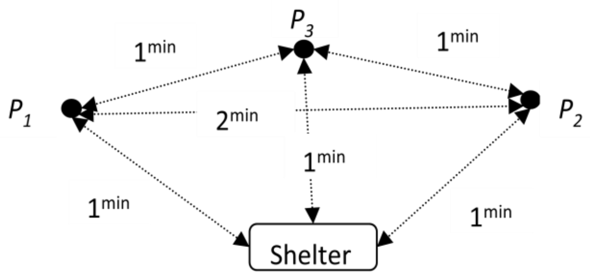


**Fig. 1(a)** Sample road network

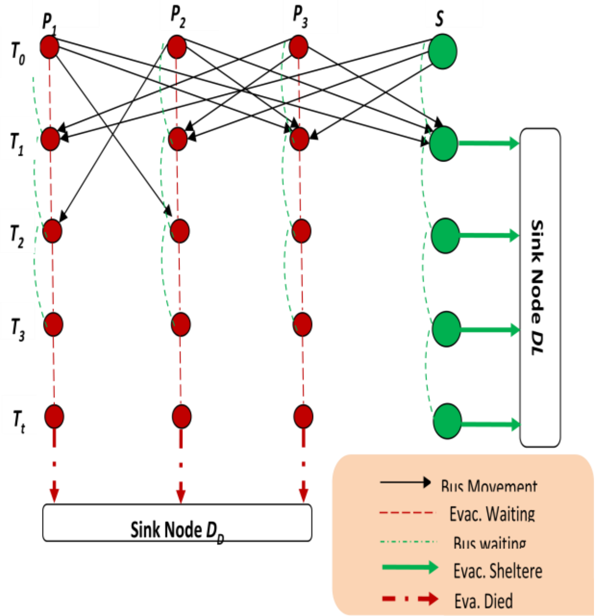


**Fig. 1(b)** Time-Space network diagram

(1) $x_{ij}$: a continuous integer variable that represents the flow of evacuees from a point $i$ to a point $j$
(2) $y_{ij}$: a binary variable that equals 1 if there is any flow of evacuees from point $i$ to point $j$, and otherwise takes the value 0. Then, the model is;

Minimize

$$\sum_{(i,j)\in A} t_{ij} x_{ij} \qquad (1)$$

Subject to

$$\sum_{\{j:(i,j)\in A\}} x_{ij} - \sum_{\{j:(j,i)\in A\}} x_{ij} = \begin{cases} \delta i & i \in P \\ 0 & i \in S \\ -\sum_{i\in P} \delta i & i \in D \end{cases} \qquad (2)$$

$$x_{ij} - C.\, y_{ij} \le 0 \qquad (i,j) \in M,\ i \in P \qquad (3)$$

$$\sum_{\{(i,j)\in M\cup Wb\}} y_{ij} \le B \qquad \text{at time } T_0 \qquad (4)$$

$$\sum_{\{j:(i,j)\in M\cup Wb\}} y_{ij} - \sum_{\{j:(j,i)\in M\cup Wb\}} y_{ij} = 0 \qquad \forall\ N\ T_t \text{ to } T_{t-1} \qquad (5)$$

$$x_{ij} \ge 0 \qquad (i,j) \in A \qquad (6)$$

$$y_{ij} \in \{0,1\} \qquad (i,j) \in M \qquad (7)$$

where
$t_{ij}$ = Travel time on arc $ij$
$N$ = Set of shelter nodes and pickup nodes
$P$ = Set of pickup nodes
$S$ = Set of shelter nodes
$D$ = Set of sink nodes ($D_L$ and $D_D$)
$A$ = Set of all types of arcs
$M$ = Set of bus movement arcs for all types of bus movements.
$W_b$ = Waiting arcs for bus
$\delta_i$= Supply of evacuees at pickup point $i \in P$
C = Capacity of the bus.
B = Total number of available buses
$T_0$ = Start time for evacuation
$T_t$ = Warning time.

## 3. CASE STUDY

A case study for the evacuation planning for Kawajima Town, Saitama, is presented in this section. A flood is expected for some of the areas in the town after a rainfall on upstream side in rainy season. Therefore, evacuation of people living therein is required and the design and planning laboratory of Saitama University has proposed to run a community bus service on a very small scale to evacuate the elderly evacuees. A maximum available evacuation time to perform evacuation operations is considered to be 1 and 1/2 h (90 min).

To set the pickup points and shelters, a field bus survey was conducted by the students of Saitama University, Japan on Saturday, 24th January 2015. At first, the town is divided into different zones and the evacuation areas specified under the Natural Disaster Prevention and Relief Law as places of refuge in emergency evacuation plans for the city[24] are assumed to be the pickup points. Fourteen points were selected accordingly. A bridge over one of the side rivers is considered to be a temporary uncapacitated shelter denoted as “S”. An approximate location of all of these points is as shown in **Fig.2**.

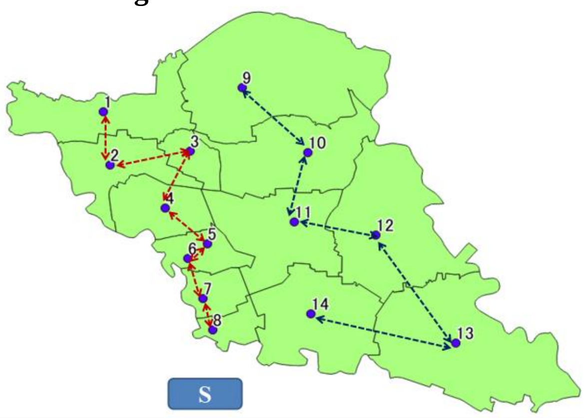


**Fig.2** Kawajima Town with zones, pickup points and shelter

From the field survey, it was clear that most of the population of the town resides on western part and is relatively sparsely located in eastern part of the town. Therefore, it appeals to be feasible for efficient evacuation operations to divide the town in two different routes; the one with pickup points from 1 to 8 lying on western side, say Route-1 and the other with rest of the pickup points 9 to 14, say Route-2. For this study, evacuation planning for only Route-1 comprised of eight pickup points and a shelter are discussed in detail. The results of the field bus survey performed on existing road network are used to compute travel times from each point to its adjacent points, as shown in **Table 1**. No any effects of congestion for this small town were observed during normal weekend day.

The demand for evacuation by each population zone is calculated for their assignment to the specified pickup points. Considering the high percentage of car possession in the town combined with the low total population, 10% of people over 65 years are expected to use the bus service for their evacuation to a public shelter. Time to appear the evacuees at a point is approximately calculated from the area served by that particular point i.e. the walking time from the farthest place lying in that zone. A uniform arrival pattern of evacuees is assumed. The number of evacuees per minute appearing at all pickup points is calculated as shown in **Table 2**.

**Table 1** Travel times for all connected nodes of Route-1

| From / To | Travel time (min) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *S* |
| *1* | 0 | 5 | - | - | - | - | - | - | 13 |
| *2* | 5 | 0 | 5 | - | - | - | - | - | 12 |
| *3* | - | 5 | 0 | 7 | - | - | - | - | 11 |
| *4* | - | - | 7 | 0 | 3 | - | - | - | 9 |
| *5* | - | - | - | 3 | 0 | 2 | - | - | 7 |
| *6* | - | - | - | - | 2 | 0 | 3 | - | 9 |
| *7* | - | - | - | - | - | 3 | 0 | 2 | 6 |
| *8* | - | - | - | - | - | - | 2 | 0 | 5 |
| *S* | - | - | - | - | - | - | - | 5 | 0 |

**Table 2** Data for evacuees at each pickup point

| Pickup point | Number of evacuees | Time to appear (min) | Evacuees supply(no./min) |
|---|---|---|---|
| *1* | 30 | 15 | 2 |
| *2* | 105 | 15 | 7 |
| *3* | 75 | 15 | 5 |
| *4* | 40 | 10 | 4 |
| *5* | 60 | 10 | 6 |
| *6* | 40 | 10 | 4 |
| *7* | 70 | 7 | 10 |
| *8* | 49 | 7 | 7 |

A comprehensive T–S network diagram is constructed by considering 1 min as the minimum time unit. Only one bus at a time is allowed to move and wait between any two nodes. A bus capacity of 25 people is used for the community bus.

## 4. RESULTS AND DISCUSSION

To analyse the different scenarios, the model was written in and solved by using the optimization toolbox function for mixed integer linear programming (intlinprog) of MATLAB R2014a. The computer used for this purpose has a 64-bit operating system and Intel(R) Core (TM) i5-2400S CPU @ 2.50 GHz, 2.50 GHz processor with an installed memory (RAM) of 4.00 GB.

### (4.1) Objective function for evacuation models

The prime objective of bus-based evacuation planning is to minimize the evacuation time, and is oftenly expressed in models as a product of time and flow (evacuees) [1,10,11] i.e. minimize $\sum t*x$. For a trip without any evacuees ($x=0$), the trip will cause no increase in the objective function value. However, practically, this trip causes loss of time. This fact can be illustrated by assuming 1 evacuee at all eight points and running the model for the two cases; one without any fixed start point, and the other with fixing start point as point 1. The results indicate two trips for the model without fixed start point. The first trip starting from point 4 and visiting five points (4, 5, 6, 7, and 8) evacuates five evacuees to the shelter. The second trip starts from shelter and visits points 1, 2, and 3 back to shelter with three evacuees. The evacuation of all eight evacuees completed in 51 min. On the contrary, fixing point 1 as a bus start point produces more plausible results i.e. evacuating all eight points in a single trip (point 1 to point 8), arriving at shelter at 32$^{nd}$ min. If we calculate the objective function value for these two cases, it comes out to be 222 for the case of without fixed start point and 256 for the one with fixed start point. This indicates that the objective function value for the case of two trips is less than the single trip, although the evacuation completion time is higher for this case.

Now we look at the results of model output for the case of Kawajima Town with real, fixed demand at all pickup points. The results are shown in **Table 3** below for the case of one bus only and rest of the results are summarized at the end as Appendix-A. The pattern of results for SBED model and factors affecting the bus trip output were observed to be similar as that of found in earlier study[1].

**Table 3** Bus trip output for one bus case

| Start Point | Evacuees sheltered by bus from pickup point | | | | | | | | No. of Evac | No. of bus trips | $T_{evac}$ (min) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | | | |
| None | 0 | 0 | 0 | 0 | 50 | 25 | 51 | 49 | 175 | 16 | 89 |
| P-1 | 25 | 0 | 0 | 0 | 50 | 0 | 70 | 30 | 175 | 14 | 88 |
| P-2 | 0 | 25 | 0 | 0 | 50 | 0 | 66 | 34 | 175 | 15 | 90 |
| P-3 | 0 | 0 | 25 | 0 | 50 | 0 | 51 | 49 | 175 | 14 | 86 |
| P-4 | 0 | 0 | 0 | 25 | 50 | 0 | 51 | 49 | 175 | 14 | 84 |
| P-5 | 0 | 0 | 0 | 0 | 59 | 13 | 54 | 49 | 175 | 17 | 88 |
| P-6 | 0 | 0 | 0 | 0 | 50 | 25 | 51 | 49 | 175 | 14 | 86 |
| P-7 | 0 | 0 | 0 | 0 | 50 | 14 | 62 | 49 | 175 | 16 | 90 |
| P-8 | 0 | 0 | 0 | 0 | 50 | 11 | 70 | 44 | 175 | 17 | 90 |

The model output for the case of without fixing any start point produced 16 bus trips to evacuate 175 evacuees till 89th min. On the other hand, fixing point 4 as astart point evacuated same 175 evacuees in 14 trips till 84th min. Even fixing point 3, and 6 produce better results in terms of evacuation time and the number of trips.

The above stated two examples emphasize the need for improvement in objective function formulation, used typically in models for evacuation planning. This improvement can be of including some cost in the objective function for the empty trips or trips without evacuees ($x$=0).

**(4.2) Demand Variations**

To observe the effect of demand variations, model was prepared and run for another two cases. For the first case, all evacuees were assumed to be present at pickup points before start of bus operation i.e. at time $t=0$. While for the second case, the evacuees were assumed to be arriiving at pickup points following the supply pattern as shown earlier in **Table 2**. From the results for these two cases, apparently it seems that results are similar as complete evacuation was observed with the use of four buses for both of the cases. However, for in-depth comparison, the results for the case of two buses are presented below in **Table 4**.

**Table 4** Bus trip results for two buses with fixed demand and continuous demand cases

| Fixed demand of evacuees | | | | | | Continuous demand of evacuees | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| * $B_1$=125 | | | $B_2$=169 | | | $B_1$=144 | | | $B_2$=150 | | |
| ***SN* | *EN* | *Evac* | *SN* | *EN* | *Evac* | *SN* | *EN* | *Evac* | *SN* | *EN* | *Evac* |
| 2 0 | S 12 | 25 | 8 0 | S 5 | 25 | ‡2 3 | S 15 | 25 | 5 0 | 6 2 | 0 |
| S 12 | 4 21 | 0 | S 5 | 7 13 | 0 | S 15 | 8 20 | 0 | 6 3 | 5 5 | 15 |
| 4 21 | S 30 | 25 | 7 13 | 8 16 | 25 | 8 20 | 7 22 | 24 | 5 5 | S 12 | 25 |
| S 30 | 7 36 | 0 | 8 16 | S 21 | 25 | 7 23 | S 29 | 25 | S 12 | 2 24 | 0 |
| 7 36 | S 42 | 25 | S 21 | 5 28 | 0 | S 29 | 7 35 | 0 | 2 24 | S 36 | 25 |
| S 42 | 6 51 | 0 | 5 28 | S 35 | 25 | 7 35 | S 41 | 25 | S 36 | 5 43 | 0 |
| 6 51 | 5 54 | 15 | S 36 | 5 43 | 0 | S 41 | 3 52 | 0 | 5 43 | S 50 | 25 |
| 5 54 | S 61 | 25 | 5 43 | S 50 | 25 | 3 52 | S 63 | 25 | S 50 | 4 59 | 0 |
| S 61 | 3 72 | 0 | S 50 | 8 55 | 0 | S 63 | 5 70 | 0 | 4 59 | S 68 | 25 |
| 3 73 | 4 80 | 10 | 8 55 | S 60 | 24 | 5 70 | S 77 | 25 | S 68 | 7 74 | 0 |
| 4 80 | S 89 | 25 | S 60 | 7 66 | 0 | S 78 | 7 84 | 0 | 7 74 | S 80 | 25 |
| | | | 7 66 | S 72 | 20 | 7 84 | S 90 | 19 | S 80 | 8 85 | 0 |
| | | | S 72 | 6 81 | 0 | | | | 8 85 | S 90 | 25 |
| | | | 6 81 | S 90 | 25 | | | | | | |

***** Number of evacuees by the bus.
****** *SN:* Start Node, *EN:* End Node (a b; where "a" is space attribute (node) and "b" is time attribute), *Eva:* No. of evacuees.
‡ The bus waited at start point 2 from $t=0$ to $t=3$.
Note: For the case of same nodes as *SN* and *EN* with time difference only, the bus is waiting at that node.

It is clear from the results that total number of evacuees possible to evacuate through two buses for the stated two cases are same (294). For the case of fixed demand case, bus 1 ($B_1$) evacuated 125 evacuees in 11 trips and bus 2 ($B_2$) evacuated 169 evacuees in 14 trips. Whereas for the case of continuous demand, $B_1$ evacuated 144 evacuees in 12 trips and $B_2$ evacuated 150 evacuees in 13 trips Total number of trips by two buses were 25 for both cases. A clear difference is observed when we look at the evacuation time along with the bus trips and the evacuees. For instance, the number of evacuees sheltered within first 61 min time are 224 for fixed demand case compared to only 150 evacuees for continuous demand case. During the remaining 29 min, the evacuees sheltered were 70 and 144 respectively. It reveals that for the case of continuous demand, once all evacuees have appeared at pickup point, the bus trips are performed more frequently and efficiently to the nearer points.

**(4.3) Evacuation Route Flexibility**

The pros and cons of introducing evacuation route flexibility in evacuation planning are briefly discussed in study by Asif-Nawaz et al[1)]. Here we illustrate it in more detail through our case study. The flexibility for bus movemenmt is comprised of three types; bus movement from a pickup point to all other pickup points, from all pickup points to shelter and from shelter to all pickup points. For the case of Route-1, we have assumed road connection of a point to its adjacent points only. Let the the case-1 be of flexible route i.e. all pickup points connected to shelter and bus can move from/to any pickup point to/from the shelter. The other case is that of restricting the bus movement to one-way only forming a complete circle i.e. from point 1 to point 8 (through points 2 to 7) to shelter and from shelter to point 1 only. The effect of flexibility to move from/to shelter can be investigated through these outputs.

The travel time for one complete one-way trip starting from point 1 to point 8 and then to shelter is 32 min. As the demand was fixed, a maximum of 50 evacuees can be evacuated by a bus in two trips within 90 min. This obvious bus trip output was observed for the case of one-way route and 10 buses were required to evacuate 469 evacuees till 67$^{th}$ min as shown in **Table 5**. However, for the case of flexible route option, only 4 buses were required to complete the evacuation. Moreover, model run-times were significantly higher for flexible route option, clearly indicating the complexity introduced in the model as a result of route flexibility. It is pertinent to note that the effect of restricting the bus movement to a specified one-way route is found here. Likewise, if we introduce more possibilities for bus movement, (e.g. from a pickup point to all other points), the effect can be more positive in terms of resources used at the cost of model complexity and run-times.

**Table 5** Evacuees and model run times

| No. of Buses | Flexible route | | One-way route | |
|---|---|---|---|---|
| | *Eva* | *Run Time (sec)* | *Eva* | *Run Time (sec)* |
| 1 | 175 | 6628 | 50 | 1 |
| 2 | 294 | 10595 | 100 | 1 |
| 3 | 335 | 10789 | 150 | 47 |
| 4 | 469 | 10600 | 200 | 256 |
| 5 | - | | 250 | 76 |
| 6 | - | | 300 | 86 |
| 7 | - | | 350 | 1041 |
| 8 | - | | 400 | 681 |
| 9 | - | | 450 | 10732 |
| 10 | - | | 469 | 10225 |

## 5. CONCLUSIONS

In this study we have used the SBED model to investigate in detail the effects of introducing evacuation route flexibility and demand variations on bus based evacuation planning. A case study for the evacuation of a small town, Kawajima, is presented with different cases. A field survey was conducted to select the possible pickup points laying on the real road network and travel time computations. It was observed that the objective function typically used for evacuation models needs improvement like incorporating travel time costs for empty trips. Secondly, although for the case of continuous demand the evacuees were assumed to arrive at pickup points quite early (15 min), yet better results in terms evacuation times were observed for fixed demand case. Thirdly, introducing the evacuation route flexibility is found to have a positive impact for reducing the resources required to evacuate the same demand.

Further research is suggested to include uncertainities about the availability of road links due to flooding in the model. For instance, there may be a case that earlier flooding can damage few links due to overflow of local drains.

## APPENDIX A

The bus trip details as per model output for complete evacuation of Kawajima town is as under.

**APPENDIX – A: Bus trip output results for the case of flexible route and fixed demand option**

| 2-Buses | | | | | | 3-Buses | | | | | | | | | 4-Buses | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***B1=125** | | | **B2=169** | | | **B1=134** | | | **B2=150** | | | **B3=125** | | | **B1=125** | | | **B2=119** | | | **B3=125** | | | **B4=100** | | |
| ***SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* | *SN* | *EN* | *Eva* |
| 2-00 | S-12 | 25 | 8-00 | S-05 | 25 | 2-00 | S-12 | 25 | 3-00 | S-11 | 25 | 3-00 | 3-01 | 0 | 3-00 | S-11 | 25 | 3-00 | 3-01 | 0 | 5-00 | S-07 | 25 | 6-00 | 7-03 | 25 |
| S-12 | 4-21 | 0 | S-05 | 7-13 | 0 | S-12 | 8-17 | 0 | S-11 | 8-16 | 0 | 3-01 | S-12 | 25 | S-11 | 8-16 | 0 | 3-01 | S-12 | 25 | S-07 | 8-12 | 0 | 7-03 | 8-05 | 25 |
| 4-21 | S-30 | 25 | 7-13 | 7-14 | 0 | 8-17 | S-22 | 24 | 8-16 | S-21 | 25 | S-12 | 7-18 | 0 | 8-16 | S-21 | 25 | S-12 | 8-17 | 0 | 8-12 | S-17 | 25 | 8-05 | 7-07 | 0 |
| S-30 | 7-36 | 0 | 7-14 | 8-16 | 25 | S-22 | 7-28 | 0 | S-21 | 7-27 | 0 | 7-18 | S-24 | 25 | S-21 | 7-27 | 0 | 8-17 | 7-19 | 5 | S-17 | 5-24 | 0 | 7-07 | S-13 | 25 |
| 7-36 | S-42 | 25 | 8-16 | S-21 | 25 | 7-28 | S-34 | 20 | 7-27 | S-33 | 25 | S-24 | 6-33 | 0 | 7-27 | S-33 | 25 | 7-19 | S-25 | 25 | 5-24 | 6-26 | 10 | S-13 | 5-20 | 0 |
| S-42 | 6-51 | 0 | S-21 | 5-28 | 0 | S-34 | 5-41 | 0 | S-33 | 5-40 | 0 | 6-33 | 5-35 | 15 | S-33 | S-34 | 0 | S-25 | 3-36 | 0 | 6-26 | S-35 | 25 | 5-20 | S-27 | 25 |
| 6-51 | 6-52 | 0 | 5-28 | S-35 | 25 | 5-41 | S-48 | 25 | 5-40 | S-47 | 25 | 5-35 | 6-37 | 0 | S-34 | S-35 | 0 | 3-36 | 2-41 | 0 | S-35 | 1-48 | 0 | S-27 | 4-36 | 0 |
| 6-52 | 5-54 | 15 | S-35 | S-36 | 0 | S-48 | 4-57 | 0 | S-47 | 4-56 | 0 | 6-37 | 5-39 | 0 | S-35 | 3-46 | 0 | 2-41 | S-53 | 25 | 1-48 | S-61 | 25 | 4-36 | S-45 | 25 |
| 5-54 | S-61 | 25 | S-36 | 5-43 | 0 | 4-57 | S-66 | 15 | 4-56 | S-65 | 25 | 5-39 | S-46 | 25 | 3-46 | S-57 | 25 | S-53 | 2-65 | 0 | S-61 | 3-72 | 0 | S-45 | S-46 | 0 |
| S-61 | 3-72 | 0 | 5-43 | S-50 | 25 | S-66 | 2-78 | 0 | S-65 | 2-77 | 0 | S-46 | 7-52 | 0 | S-57 | S-58 | 0 | 2-65 | S-77 | 25 | 3-72 | 4-79 | 10 | S-46 | S-47 | 0 |
| 3-72 | 3-73 | 0 | S-50 | 8-55 | 0 | 2-78 | S-90 | 25 | 2-77 | S-89 | 25 | 7-52 | 6-55 | 0 | S-58 | 2-70 | 0 | S-77 | 8-82 | 0 | 4-79 | 5-82 | 25 | S-47 | 2-59 | 0 |
| 3-73 | 4-80 | 10 | 8-55 | S-60 | 24 | | | | | | | 6-55 | 5-57 | 0 | 2-70 | 1-75 | 20 | 8-82 | S-87 | 19 | 5-82 | 5-83 | 0 | 2-59 | 3-64 | 10 |
| 4-80 | S-89 | 25 | S-60 | 7-66 | 0 | | | | | | | 5-57 | 6-59 | 0 | 1-75 | S-88 | 25 | | | | 5-83 | S-90 | 25 | 3-64 | 2-69 | 0 |
| | | | 7-66 | S-72 | 20 | | | | | | | 6-59 | S-68 | 25 | | | | | | | | | | 2-69 | S-81 | 25 |
| | | | S-72 | 6-81 | 0 | | | | | | | S-68 | 3-79 | 0 | | | | | | | | | | | | |
| | | | 6-81 | S-90 | 25 | | | | | | | 3-79 | S-90 | 25 | | | | | | | | | | | | |

* Total number of evacuees by the bus.
** SN: Start Node, EN: End Node (a-b; where "a" is the space attribute (pickup point number/shelter) and "b" is the time attribute), Eva: Number of evacuees.

Note;
For the case of same nodes as SN and EN, the bus is waiting at that node.

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