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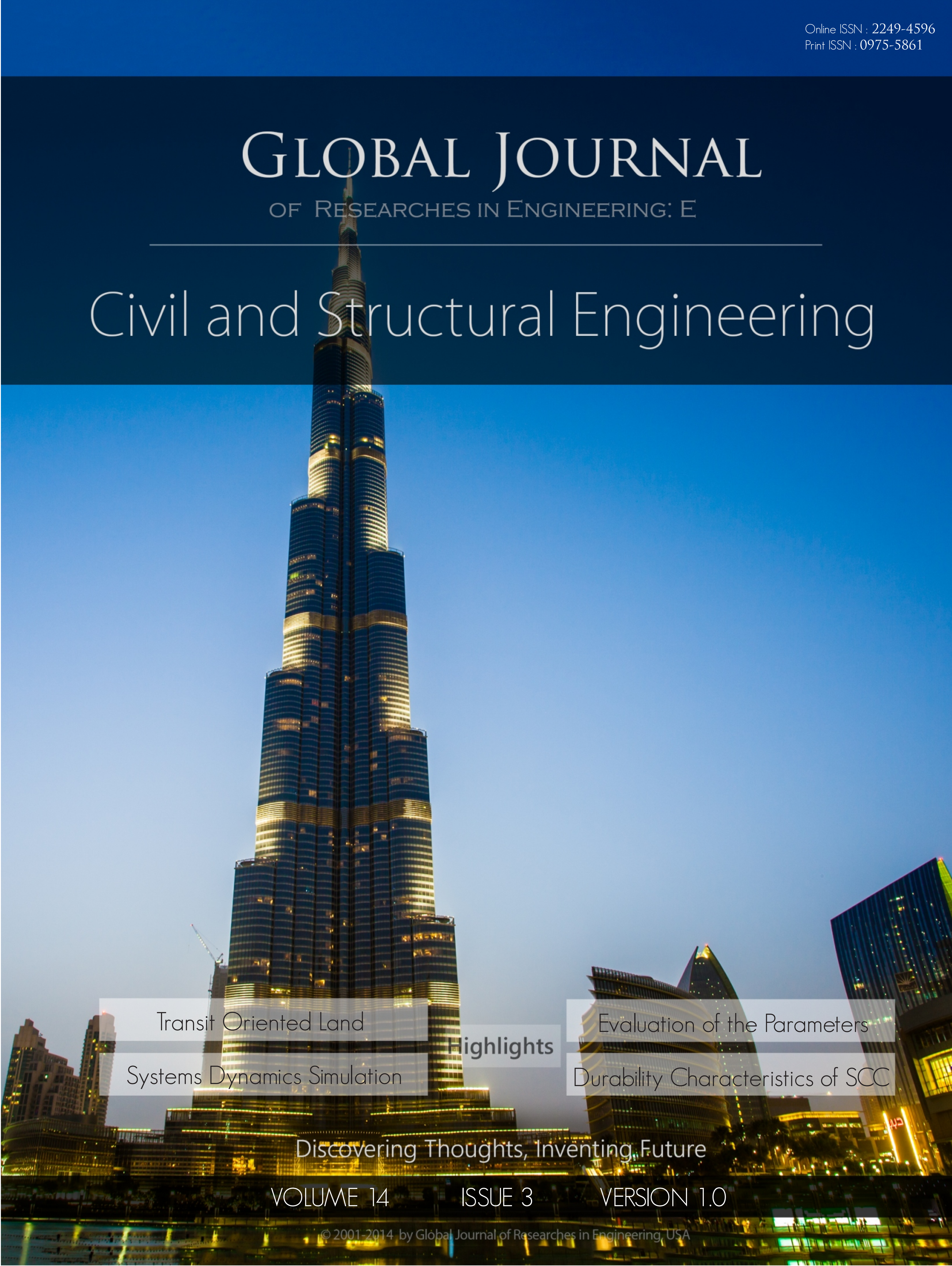

Highlights

Transit Oriented Land

Systems Dynamics Simulation

Evaluation of the Parameters

Durability Characteristics of SCC

Discovering Thoughts, Inventing Future

VOLUME 14 ISSUE 3 VERSION 1.0

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Vibrations in Steel-Frame Floors due to Human Activities

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Abstract- Architectural new tendencies along with current market demands are taking engineering design towards the use of flooring systems which can span great distances with a minimum number of columns allowing, thus, more architectural flexibility. This design philosophy has conducted to ever more slender structural elements, with ever lower natural frequencies that are, therefore, closer to the frequency bands of dynamic excitations associated to human activities, such as walking. Within this context, this paper studies the behaviour of the following flooring systems: (a) reinforced concrete slabs supported by steel beams, and (b) steel floor plates supported by steel beams. The evaluation of the natural frequencies of the structure and its responses (floor displacements and accelerations) to the walking activity were analyzed by the simplified analytical method of AISC 360-10 code. The flooring systems were modeled using the finite element software ANSYS 14.0™ and the numerical results for natural frequencies and floor accelerations were compared with those obtained by the simplified procedure of the AISC 360-10 code. This way, it was possible to draw conclusions about the dynamic behaviour of the analyzed flooring systems.

Keywords: flooring systems, walking loading, dynamic behaviour, structural vibrations.

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Mateus Zimmer Dietrich [α], Felipe Barbosa Teixeira [σ], Adenilcia Fernanda Grobério Calenzani [ρ] & Walnório Graça Ferreira [Ѡ]

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Keywords: flooring systems, walking loading, dynamic behaviour, structural vibrations.

I. Introduction

Architectural new tendencies along with current market demands are taking engineering design towards the use of flooring systems which can span great distances with a minimum number of pillars allowing, thus, more architectural flexibility. This design philosophy has conducted to ever more slender structural elements, with ever lower natural frequencies that are, therefore, closer to the frequency bands of dynamic excitations associated to human activities, such as walking.

Within this context, studies about the dynamic behaviour of commonly employed flooring systems become necessary for the evaluation of the service conditions of buildings subject to vibrations caused by human activities such as walking.

Brazilian Standard NBR 8800:2008 covers this topic very superficially. Annex L points restrictions only on the natural frequency of the floor, furnishing a simplified evaluation that depends on the total vertical displacement of the floor. However, the standard signals that this evaluation might not be adequate for the problem and leaves its application to the discretion of the engineer.

The CEB (1991) standard treats the subject in a broader manner, furnishing graphical and analytical representations for human activities, pointing some factors that influence the damping of a structure, the effects caused by vibrations on people and on the structure, tolerable acceleration values, corrective measures, and more. It is interesting to point out that the manual presents two simplified design rules. The first, High Tuning Method, being simple and efficient, limits the fundamental frequency of the floor with respect to its damping rate. This method, though, can be quite conservative. And the second, Method of Heel Impact, presents simple procedures for the computation of the frequency and initial peak acceleration of the floor.

The AISC 360-10 standard, through Murray et al. (2003) Design Guide, also treats the subject and presents simple analytical tools for the verification of flooring systems subjected to vibrations. In a similar way to the method described by CEB, firstly the frequency is calculated, followed by the peak acceleration. The standard not only presents a broader application as compared to the most commonly used methods, but also has its own criterion based on the dynamic response of flooring systems supported by steel beams subject to walking loading, consisting, therefore, the utilized tool in this study.

Following this directive, Mello (2005) developed numerical analyses in flooring systems subject to human activities and compared the obtained results with the simplified calculation method of AISC 360-10. Pretti (2012) performed a study about the different simplified procedures for determining peak acceleration of flooring systems subject to human activities and applied these procedures in numerical examples.

II. Simplified Calculation Method

The Steel Design Guide by Murray et al. (2003) presents, in accordance to American Standard AISC 360-10, a simplified analytical method for determining the frequency and the acceleration of a flooring system.

The following described method is applied to floor panels subject to the human activity of walking, made of concrete slabs or composite slabs with steel beams.

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a) Floor Natural Frequency

The most important parameter for the verification of the service limit state of excessive vibration in flooring panel systems is the natural frequency. Following, a simplified procedure for the determination of the vertical fundamental frequency of the flooring system is presented.

A simply supported beam, with uniform distributed load, has its natural frequency given by Eq. (1).

$$f_n = 0.18\sqrt{\frac{g}{\Delta}}, \quad (1)$$

where:

f_n = natural fundamental frequency of the beam [Hz];

g = gravity acceleration, 9.81 m/s^2;

Δ = beam deflection.

The deflection of a simply supported beam subject to uniformly distributed loading is calculated by Eq. (2).

$$\Delta = \frac{5wL^4}{384 E_S I_T}, \quad (2)$$

where:

w = uniformly distributed weight per unit length (actual, not design);

L = element length;

E_S = steel elasticity modulus, 200000 MPa;

I_T = moment of inertia of the transformed section.

A flooring system is composed by slabs supported in beams which are supported by girders, these later supported by columns. The natural frequency of the flooring system is estimated as a function of the frequency of the beam panel and the frequency of the girder panel, combining both. For this, Dunkerley´s relation is used to derive the combined mode, Eq. (3):

$$\frac{1}{f_n^2} = \frac{1}{f_j^2} + \frac{1}{f_g^2}, \quad (3)$$

where:

f_j = beam panel mode frequency;

f_g = girder panel mode frequency.

The combined mode or system frequency can be estimated using Dunkerley relationship, given by Eq. (4):

$$f_n = 0.18\sqrt{\frac{g}{(\Delta_j + \Delta_g)}}, \quad (4)$$

where:

Δ_j = deflection of the beam panel;

Δ_g = deflection of the girder panel;

b) Floor Acceleration

Most vibration problems caused by human activities involve periodic loadings, with respect to time, though walking presents itself a bit more complicated since the location of the forces also varies with time. In general, a periodic loading can be represented by a combination of sinusoidal forces with frequencies that are multiple or harmonics of a basic frequency, named step frequency, for human activities. The load can then be represented by a Fourier series given by Eq. (5).

$$P(t) = P\left[1 + \sum \alpha_i \cos\left(2\pi i f_{step}\, t + \phi_i\right)\right], \quad (5)$$

being:

P = person´s weight, equal to 700N;

α_i = dynamic coefficient for the harmonic i;

f_{step} = activity step frequency;

ϕ_i = phase angle for harmonic i;

t = time variable [s].

This project criterion uses as loading a single time dependent harmonic component with a frequency equal to the floor fundamental frequency, according to Eq. (6). Only one component of Eq. (5) is used since all the other harmonic vibrations are low when compared with the resonance associated harmonic.

$$P(t) = P\alpha \cos(2\pi f_n t). \quad (6)$$

The response function in resonance is given by Eq. (7).

$$\frac{a_P}{g} = \frac{PR\alpha_i}{\beta W}\cos(2\pi f_n t), \quad (7)$$

where:

a_P/g = ratio between estimated peak acceleration and gravity acceleration;

R = reduction factor;

β = floor system damping rate;

W = effective floor weight.

The reduction factor R takes into account the fact that stationary resonant movement is not achieved during the walk and that the person walking and the perturbed person are not simultaneously on the maximum displacement location. It is recommended to use R equal to 0.7 for walkways and 0.5 for flooring systems. The effective weight of the floor will be estimated on the next subsection.

Equation (7) can be simplified by using an approximated function for the dynamic coefficient as a function of the frequency, Eq. (8).

$$\alpha = 0.83\exp(-0.35f) \quad (8)$$

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Finally, a flooring system will be considered satisfactory if it obeys Eq. (9).

$$\frac{a_P}{g} = \frac{P_0 exp\,(-0.35 f_n)}{\beta W} \leq \frac{a_0}{g}, \quad (7)$$

where:

a_0/g = limit acceleration as a function of the type of building;

The limit values P_0, β, and a_0/g, recommended for general occupation are given by Table 1.

Table 1 : Recommended values for Eq. (9) parameters

Purpose	Constant force P_0	Damping Rate **β**	Limit acceleration a_0/g.100%
Offices, residences and churches	0.29 kN	0.02 – 0.05*	0.5%
Shopping centers	0.29 kN	0.02	1.5%
Footbridge-Indoor	0.41 kN	0.01	1.5%
Footbridge-Outdoor	0.41 kN	0.01	5.0%
*0.02 for floors with few non-structural components (ceilings, ducts, partitions, etc.) as can occur in open work areas or churches; 0.03 for floors with non-structural components and furnishings, but with only small demountablepartition, typical of many modular office areas; 0.05 forfull height partitions between floors.			

Source: Murray et al. (2003)

c) Effective panel weight

In general, effective weights for the beam and girder panel modes can be calculated by Eq. (10).

$$W = \omega BL, \quad (8)$$

where:

ω = weight per unit area;

L = memberspan;

B = effective width.

For the beam, the effective width is defined as:

$$B_j = C_j \left(\frac{D_S}{D_j}\right)^{1/4} L_j. \quad (9)$$

This value is not allowed to be greater than 2/3 of the floor width, L_g,[1] where:

C_j = 2.0 for most areas;

= 1.0 for beams parallel to an interior boundary;

D_S = moment of inertia of the transformed slab by unit width;

= $d_e^3/(12n)$ [mm];

d_e = effective thickness of the concrete slab, usually taken as the thickness of the concrete above the steel form plus half the thickness of the steel form;

n = dynamic modular ratio = $E_S/1.35E_C$;

E_S = Steel elasticity modulus;

E_C = Concrete elasticity modulus;

D_j = transformed moment of inertia of the beamper unit width;

= I_T/S [mm];

I_T = effective moment of inertia of the transformed section;

S = beam spacing;

L_j = beam span.

For the girder, the effective width is defined as:

$$B_g = C_g \left(\frac{D_j}{D_g}\right)^{1/4} L_g. \quad (10)$$

This value is not allowed to be larger than 2/3 of the floor length, L_j,[2] where:

C_g = 1.6 for girders supporting beams connected to the girder flange;

= 1.8 for girders supporting beams connected to the girderweb;

D_g = transformed moment of inertia of the girder by unit width;

= I_g/L_j for all but edge girders;

= $2I_g/L_j$ for edge girders;

L_g = girder span.

When the beams are continuous over their supports and with an adjacent span is greater than 0.7 times the span under consideration, the effective panel

[1] The floor width must be multiplied by 3 when dealing with a typical internal room.

[2] The floor length must be multiplied by 3 when dealing with a typical internal room.

weight, W_j or W_g, can be increased by 50%. This liberalization can also be applied to rolled steel beams connected (by shear) to the web of the girder, but not to trusses connected only at their top chord.

For the combined mode, the equivalent panel weight is approximated using Eq. (13).

$$W = \frac{\Delta_j}{\Delta_j + \Delta_g} W_j + \frac{\Delta_g}{\Delta_j + \Delta_g} W_g, \quad (11)$$

where:

Δ_j and Δ_g = maximum deflexions of the beam and girder, respectively, due to the supported load;

W_j and W_g = effective panel weights for the beam and girders panels, respectively.

If the girder span is less than the width of the beam panel, $L_g < B_j$, the girder deflection, Δ_g, used in Eq. (13) is reduced to:

$$\Delta_g' = \frac{L_g}{B_j}(\Delta_g), \quad (12)$$

and

$$0.5 \le {}^{L_g}\!/_{B_j} \le 1.0.$$

If $L_j < 0.5L_g$, the beam panel mode and the combined mode should be separately verified.

d) Internal Tooredges

Internal flooredges, require special consideration as a consequence of the reduced mass reduction due to the free edge.

When the edge member is a beam, the practical solution is to stiffen the edge, either by the addition of another beam or by the substitution of this member by another one that should have a 50% higher moment of inertia. If edge beam is not stiffened, its verification should be made using $C_j = 1.0$ on Eq. (11).

When the edge member is a girder, the verification should be made according to the described procedure, except by the fact that the effective width (B_g) should be taken equal to 2/3 of the secondary supported beam span.

The experience has shown that external floors edges of buildings do not require special attention such as the internal floor edges. The reason for this is the stiffening due to the external cladding and walkways which in general are not adjacent to external walls.

III. Simplified Calculation Method

a) About the used Software

For the numerical analysis was used the ANSYS 14.0™. This software is quite rich with respect to the element library, the possible types of structural analysis, and the available numerical resources. Besides that, ANSYS 14.0™ has been well utilized by the scientific community in numerical simulations to analyze the dynamic behaviour of structures.

b) Structural Model

The structural models analyzed in this paper represent an internal floor compartment, constituted by slabs or steel floor plates supported by beams that are supported by girders or columns, as in Fig. 1. The columns are not modeled. The dynamic load, $P(t)$, due to walking activity, is applied only at the center of the model.

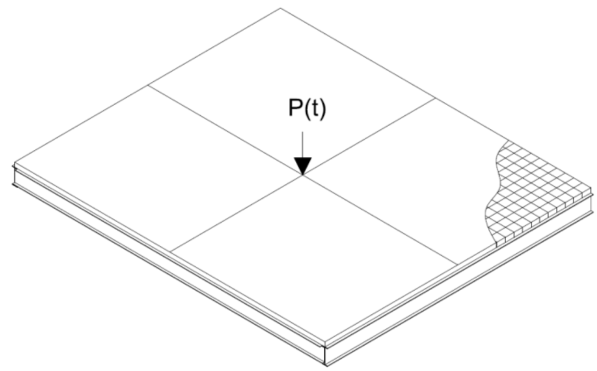

Figure 2 : Floor model – Isometric view

The beams and girders were modeled using the element BEAM 188 3-D, that has six degrees of freedom at each node, three translations and three rotations. There is yet the seventh degree of freedom, the cross section warping, which is optional and was not used in this work. The cross section mesh for this element has a refinement option that can vary from 0 to 5. For the present work was adopted a refinement value of 2.

The slabs and the steel floor plates were modeled using the SHELL 181 element, consisting of 4 nodes and having 6 degrees of freedom per node, three translations and three rotations. This element is adequate for the analysis of thin shells or moderately thick shells, simulating both the flexure and the membrane effects.

Both elements might be displaced with respect to their geometric axis assuring, therefore, the correct placement of the slabs and the floor plates with respect to the beams.

The mesh dimensions were defined from free vibration analysis of a flooring system similar to model I, described later, with beams span of 9.0m. Analyzing Table 2, it is observed that in meshes with dimensions smaller than 0.30m, the natural frequencies present small percent deviations when compared to the 0.05m mesh. Thus, a square mesh of 0.25m side was adopted, since it gives an exact number of divisions for the models dimensions.

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Table 2 : Mesh refinement

# Mesh [m]	f_n [Hz]	Percent Deviation
0.05	5.2946	-
0.10	5.2961	0.028%
0.15	5.3008	0.117%
0.20	5.3059	0.213%
0.25	5.3110	0.310%
0.30	5.3169	0.421%
0.50	5.3436	0.925%
0.60	5.3586	1.209%
0.75	5.3833	1.675%
1.00	5.4321	2.597%
1.50	5.5586	4.986%

Two types of floors were modeled, according to the following description.

c) Structural Model I

This model is constituted by a plan concrete slab with characteristic strength f_{ck} equal to 30MPa, specific mass of 2500kg/m^3, Poisson´s ratio 0.2, and 0.15m thickness. Steel girder sections W530x74.0 of length equal to 9.0m, and steel beam sections W460x52.0, equally spaced to each other at a 3.0m distance, as in Fig. 2. The beam span, L_j, was varied from 6.0 to 10.5m in intervals of 0.5m.

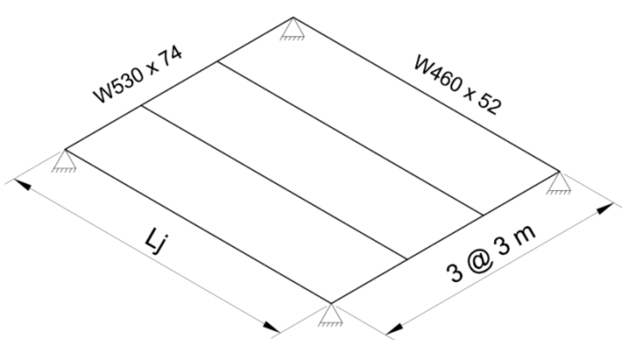

Fig. 2 : Isometric view – Structural model I

It was chosen to represent an office floor, and thus a damping rate of 3% was adopted, according to Table 1. The loading to be applied is not the design load as described by the procedure in section II. It was used, then, as variable loading, 0.70kN/m^2, of which 0.50kN/m^2 accounts for the use and occupation and 0.20kN/m^2 for the mechanical equipment and covering.

d) Structural Model II

This model is constituted by 8mm steel plates supported by beam sections W310x28.3. Steel girder sections W460x60.0 have length equal to 9.0m, as in Fig. 3. The beam span, L_j, was varied from 1.5 to 10.5m in intervals of 1.0m. The support of the floor plates in transversal directionregarding to beams were not considered in the model since they have a lesser influence on the dynamic behavior, given their reduced mass and stiffness. In this way, models with higher number of nodes and elements were avoided.

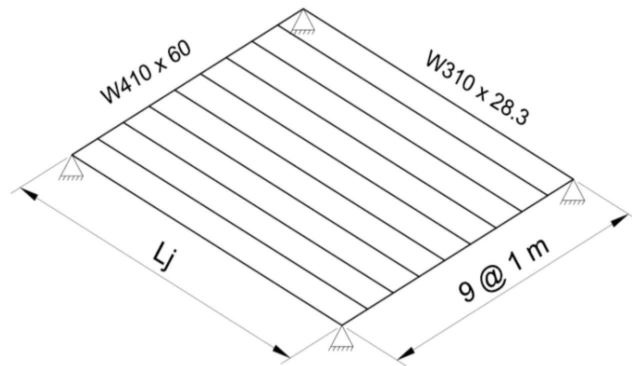

Fig. 3 : Isometric view – Structural model II

This model was also conceived to represent an office floor, and thus the same damping rate of 3% was adopted. The variable loading acting adopted was the same value applied to model I, i.e., 0.70kN/m^2. The objective of this model was to evaluate the dynamic behaviour of a flooring system composed solely of steel elements.

e) Loading Parameters

The walking loading was modeled in a simplified manner, similar to what is described in section II, by considering only one frequency harmonic equal to the fundamental frequency of the flooring system. Thus, the $P(t)$ load in N applied to the floor central point is given by Eq. (15).

$$P(t) = 700[0.83\exp(-0.35 f_n)]\cos(2\pi f_n t). \qquad (13)$$

f) Structur Alanalysis

The dynamic analysis performed in ANSYS 14.0™ was linear elastic, without the consideration of initial imperfections. The software allows dynamic equilibrium equations resolution both by direct integration or by the modal superposition method. The direct integration method was the chosen option.

The time interval used in the integration was of 0.005s and the algorithm for the integration of the equations chosen in ANSYS 14.0™ was Newmark´s linear acceleration. For this algorithm, according to Clough and Penzien (1995), a time interval Δt less or equal 10% of the excitation period yields trustworthy results. Furthermore, Bathe (1996) shows that precise values are obtained with a time interval of approximately 1% of the excitation period.

ANSYS 14.0™ adopts a damping matrix proportional to the mass and stiffness matrices. For this,

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the user must provide the values of the constants α and β , that are calculated according to Eq. (16):

$$\begin{Bmatrix}\alpha\\ \beta\end{Bmatrix} = \frac{2\xi}{\omega_m + \omega_n}\begin{Bmatrix}\omega_m \omega_n\\ 1\end{Bmatrix}, \qquad (14)$$

where:

ξ = damping rate;

$\omega_{m,n}$ = angular frequencies of two vibration modes [rad/s].

IV. Results

The analyzed results are the natural frequencies and the accelerations of the floors subjected to Eq. (15) dynamic loading. Several simulations were carried out for both structural models, varying, for each simulation, the beam length, L_j .

a) *Structural Model I*

The fundamental frequencies for this model are listed in Table 3.

Table 3 : Fundamental frequencies from the computational model

L_j [m]	FundamentalFrequencies[Hz]									
	f_{01}	f_{02}	f_{03}	f_{04}	f_{05}	f_{06}	f_{07}	f_{08}	f_{09}	f_{10}
10.5	4.43	6.85	9.61	10.18	16.92	18.78	19.57	24.38	29.64	32.41
10.0	4.71	7.42	9.92	10.77	17.82	19.30	20.83	25.81	31.58	32.79
9.5	5.00	8.07	10.23	11.45	18.85	19.91	22.20	27.32	33.25	33.79
9.0	5.31	8.80	10.56	12.26	20.02	20.64	23.69	28.94	33.81	36.29
8.5	5.63	9.63	10.91	13.21	21.38	21.52	25.31	30.68	34.50	39.11
8.0	5.96	10.58	11.28	14.33	22.59	22.97	27.07	32.59	35.36	42.28
7.5	6.31	11.65	11.67	15.65	23.90	24.83	28.98	34.72	36.47	45.82
7.0	6.67	12.08	12.88	17.20	25.51	27.03	31.08	37.16	37.90	49.53
6.5	7.05	12.54	14.29	18.99	27.50	29.64	33.37	39.82	40.01	53.24
6.0	7.45	13.03	15.90	21.06	29.98	32.76	35.88	42.41	43.40	57.50

For the computation of the α and β constants were utilized the frequencies f_{01} and f_{03} , as shown in Table 4.

Table 4 : Parameters α and β for forced vibration evaluation

Lj [m]	f_{01} [Hz]	f_{03} [Hz]	$0.83\exp(-0.35.f_{01})$	ξ	α	β
10.5	4.43	9.61	0.1761	0.03	1.143	0.000680
10.0	4.71	9.92	0.1597	0.03	1.204	0.000653
9.5	5.00	10.23	0.1441	0.03	1.267	0.000627
9.0	5.31	10.56	0.1294	0.03	1.332	0.000602
8.5	5.63	10.91	0.1156	0.03	1.400	0.000577
8.0	5.96	11.28	0.1029	0.03	1.471	0.000554
7.5	6.31	11.67	0.0911	0.03	1.544	0.000531
7.0	6.67	12.88	0.0803	0.03	1.657	0.000488
6.5	7.05	14.29	0.0704	0.03	1.780	0.000448
6.0	7.45	15.90	0.0613	0.03	1.912	0.000409

With transient vibration analysis, the response for displacement and acceleration of the floor central node is obtained. Figures 4 and 5 show, respectively, the history of displacement and acceleration of model I with beams of length equal to 8.0m, i.e., L_j=8.0m.

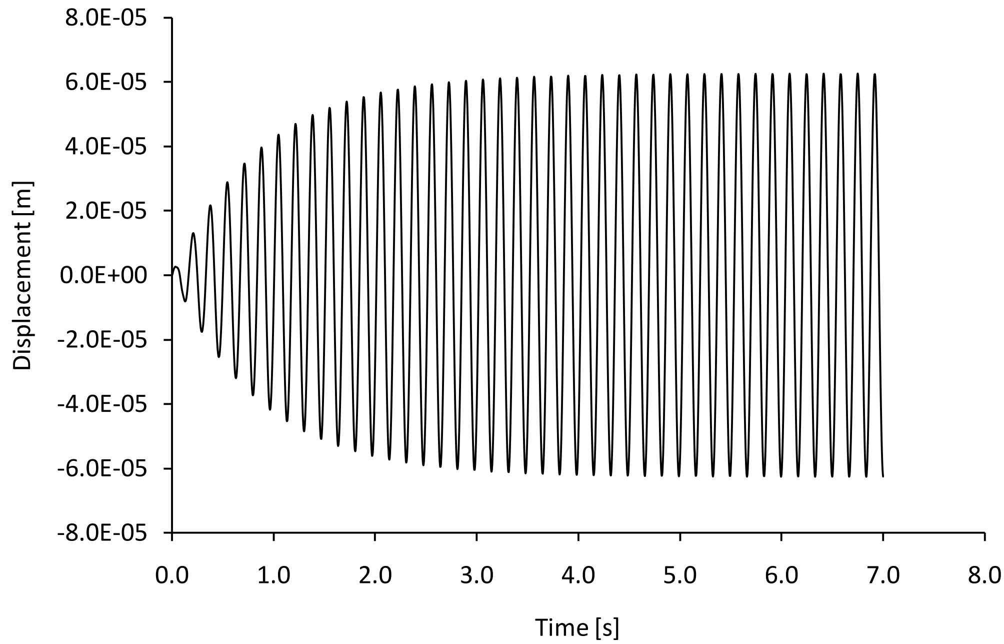

Fig. 4 : Vertical displacement for the computational model with L_j =8.0m

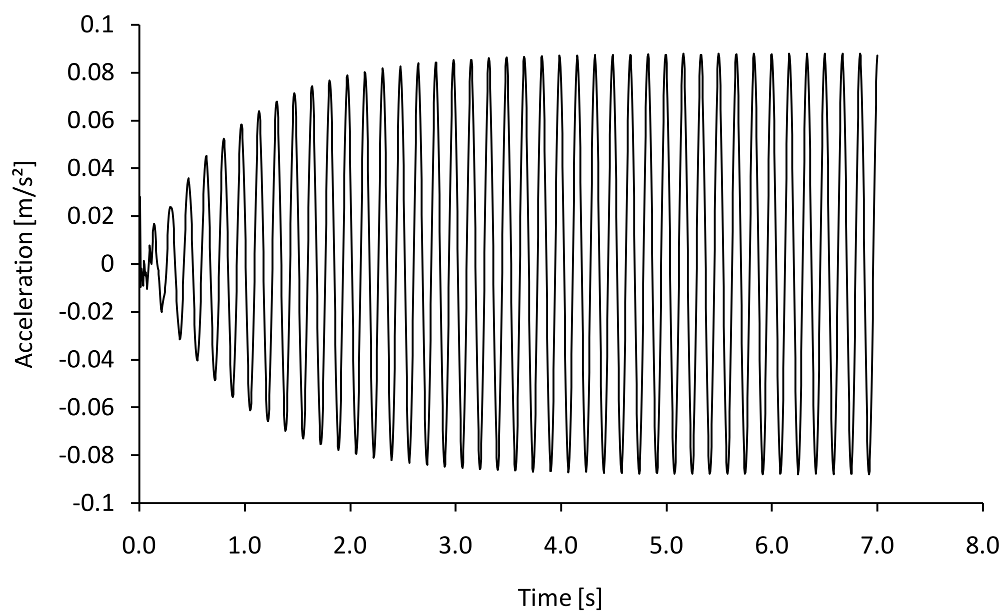

Fig. 5 : Vertical acceleration for the computational model with L_j =8.0m

At Table 5 are displayed the fundamental frequency results obtained by ANSYS 14.0™ and by the simplified procedure of the AISC 360:10 code. Comparing these results, a slight percent difference can be noticed.

Table 5 : Natural frequencies

L_j [m]	Computational Model	AISC	Percent Deviation
10.5	4.43	4.06	8.33%
10.0	4.71	4.34	7.84%
9.5	5.00	4.65	7.07%

9.0	5.31	4.98	6.23%
8.5	5.63	5.34	5.17%
8.0	5.96	5.72	4.10%
7.5	6.31	6.13	2.87%
7.0	6.67	6.61	0.94%
6.5	7.05	7.11	-0.85%
6.0	7.45	7.63	-2.46%

Table 6 presents the results for peak acceleration obtained by ANSYS 14.0™ and by the simplified procedure of the AISC 360:10 code. The ratio between the time interval and the period, Δ/, utilized in the models is within the interval from 0.0221 to 0.0372.

Table 6 : Peak accelerations

Lj [m]	ComputationalModel	0.5[(1)] x ComputacionalModel	AISC	LIMIT0.5%g[(2)]
10.5	0.1149	0.0574	0.0790	0.0491
10.0	0.1103	0.0552	0.0750	0.0491
9.5	0.1053	0.0527	0.0707	0.0491
9.0	0.0999	0.0499	0.0679	0.0491
8.5	0.0940	0.0470	0.0648	0.0491
8.0	0.0880	0.0440	0.0611	0.0491
7.5	0.0818	0.0409	0.0570	0.0491
7.0	0.0756	0.0378	0.0516	0.0491
6.5	0.0697	0.0348	0.0462	0.0491
6.0	0.0639	0.0320	0.0411	0.0491

(1) Reduction factor, R.
(2) The value for limit acceleration was calculated for g=9.81m/s^2. This value is also suggested by CEB(1991).

The plots at Figures 6 and 7 show, respectively, the variation of the fundamental frequency and the peak acceleration with the value of the beam span.

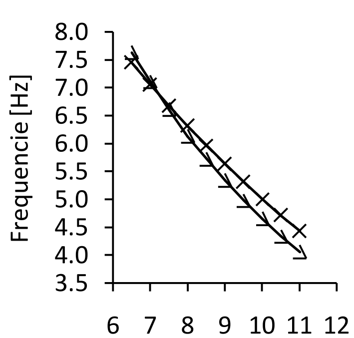

Fig. 6 : Variation of the fundamental frequency of the floor with the secondary beam span

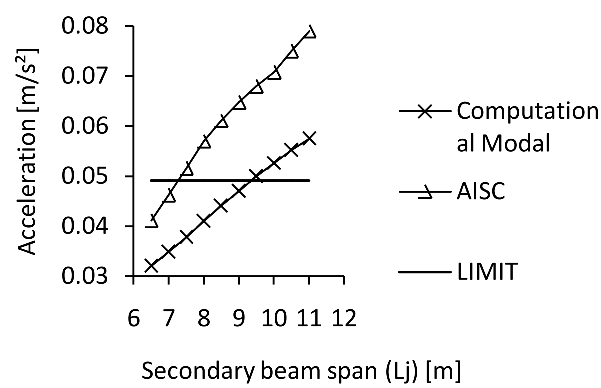

Fig.7 : Variation of the vertical acceleration of the floor with the secondary beam span

b) Structural Model II

Firstly, there are the fundamental frequencies, shown in Table 7.

Table 7 : Fundamental frequencies from the computational model

L_j [m]	Fundamental Frequencies [Hz]									
	f_{01}	f_{02}	f_{03}	f_{04}	f_{05}	f_{06}	f_{07}	f_{08}	f_{09}	f_{10}
10.5	4.13	5.35	5.80	6.24	6.88	7.70	8.74	9.19	9.97	11.48
9.5	4.68	6.39	6.92	7.38	8.01	8.82	9.73	9.84	11.03	12.38
8.5	5.31	7.74	8.41	8.88	9.47	10.21	10.30	11.12	12.11	13.08
7.5	6.00	9.53	10.41	10.85	10.90	11.36	11.92	12.55	13.15	13.60
6.5	6.77	11.57	11.91	12.94	13.13	13.54	13.97	14.19	14.35	14.39
5.5	7.61	12.32	14.46	14.55	15.06	15.37	16.20	16.79	17.01	17.18
4.5	8.55	13.20	15.85	16.11	17.04	18.34	18.99	19.75	20.92	21.36
3.5	9.66	14.27	18.59	18.98	19.94	21.39	23.13	23.53	24.91	26.15
2.5	11.11	15.61	24.99	25.46	26.33	27.57	28.46	29.10	30.70	31.80
1.5	13.36	17.13	34.92	39.09	39.30	39.63	40.06	40.33	40.64	40.82

Similarly to model I, the frequencies f_{01} and f_{03} were utilized for the computation of the α andβ constants, as shown in Table 8.

Table 8 : Parameters α and β for forced vibration evaluation

Lj [m]	f_{01} [Hz]	f_{03} [Hz]	0.83exp(-0.35.f_{01})	ξ	α	β
10.5	4.13	5.80	0.1954	0.03	0.909	0.000962
9.5	4.68	6.92	0.1611	0.03	1.053	0.000823
8.5	5.31	8.41	0.1295	0.03	1.227	0.000696
7.5	6.00	10.41	0.1016	0.03	1.435	0.000582
6.5	6.77	11.91	0.0777	0.03	1.626	0.000511
5.5	7.61	14.46	0.0579	0.03	1.879	0.000433
4.5	8.55	15.85	0.0417	0.03	2.093	0.000391
3.5	9.66	18.59	0.0282	0.03	2.397	0.000338
2.5	11.11	24.99	0.0170	0.03	2.900	0.000265
1.5	13.36	34.92	0.0077	0.03	3.642	0.000198

At Table 9 are displayed the fundamental frequency results obtained by ANSYS 14.0™ and by the simplified procedure of the AISC 360:10 code. Comparing these results, a slight percent difference can be noticed. Fig. 8 plot shows the variation of fundamental frequency plotted against the span of the beam.

Table 9 : Natural frequencies

L_j [m]	Computational Model	AISC	Percent Deviation
10.5	4.13	4.04	2.24%
9.5	4.68	4.57	2.44%
8.5	5.31	5.18	2.41%
7.5	6.00	5.86	2.36%
6.5	6.77	6.61	2.31%
5.5	7.61	7.45	2.05%
4.5	8.55	8.41	1.61%
3.5	9.66	9.57	0.94%
2.5	11.11	11.08	0.31%
1.5	13.36	13.40	-0.32%

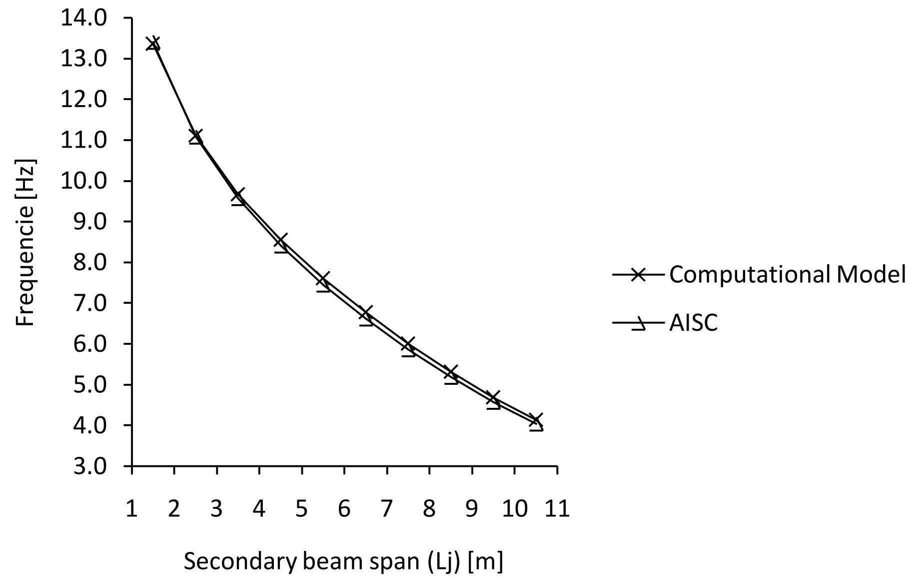

Fig. 8 : Variation of the fundamental frequency of the floor with the secondary beam span

Table 10 presents the results for peak acceleration obtained by ANSYS 14.0™ and by the simplified procedure of the AISC 360:10 code. The ratio between the time interval and the period, Δ_t/T, utilized in the models is within the interval from 0.0207 to 0.0668.The plot at Fig. 9 shows the variation of the peak acceleration with the value of the secondary beam span.

Table 10 : Peak accelerations

Lj [m]	Computational Model	$0.5^{(1)}$ x Computational Model	AISC	LIMIT $0.5\%g^{(2)}$
10.5	0.4751	0.2376	0.3722	0.0491
9.5	0.4384	0.2192	0.3124	0.0491
8.5	0.3765	0.1882	0.2564	0.0491
7.5	0.3115	0.1558	0.2073	0.0491
6.5	0.2538	0.1269	0.1664	0.0491
5.5	0.2050	0.1025	0.1337	0.0491
4.5	0.1653	0.0826	0.1074	0.0491
3.5	0.1298	0.0649	0.0853	0.0491
2.5	0.0974	0.0487	0.0641	0.0491
1.5	0.0605	0.0302	0.0408	0.0491

(1) Reduction factor, R.

(2) The value for limit acceleration was calculated for $g = 9.81 m/s^2$. This value is also suggested by CEB (1991).

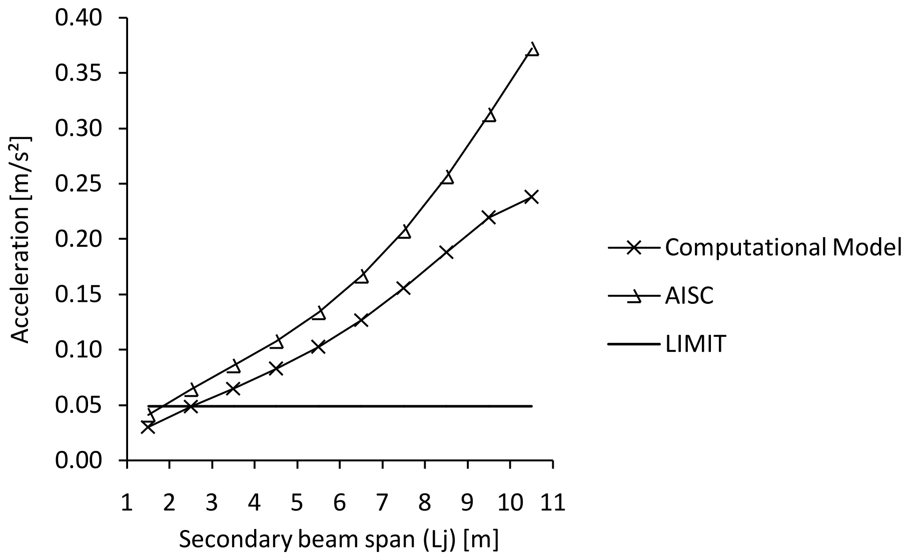

Fig. 9 : Variation of the vertical acceleration of the floor with the secondary beam span

V. Conclusion

Two representative models of flooring systems were simulated in the ANSYS 14.0™ finite element software to study their dynamic behaviour due to loadings caused by the human activity of walking. Both models simulate an inner compartment of an office floor, their difference being that model I is composed by concrete slabs and steel beams and model II is composed by floor plates and steel beams. The numerical results were confronted with the analytical formulation of the AISC 360:10 code.

When analyzing the percent deviation of Tables 5 and 9, it is concluded that this value increases as the span length L_j increases. Probably, this is due to the fact that Eq. (4) of the AISC code calculates the system frequency from the static displacements of the beams and girders, assuming a simplified uniformly distributed load for both beams. At the ANSYS 14.0™ models, these simplifications were not made.

Model I presents accelerations greater than the allowed limit when the span length of the beam exceeds 9m. Therefore, vibration analysis becomes an important factor for the type of occupation studied and should be taken into account in the design of the building floor.

With respect to model II, the floor presents peak acceleration values higher than the limit for small spans of the beam, above 2.5m. This shows that the flooring system is far more susceptible to vibrations than the model I system, and does not configure a good structural solution for the studied type of occupation.

Still in relation to the obtained results of accelerations, plots at Fig. 7 and Fig. 10, the same behaviour which occurred for the fundamental frequencies can be observed: increase of the differences between the results calculated by the finite element software and by the AISC code with the increase of the beam span L_j. This probably occurs due to the conditions imposed on the computation of the effective widths B_j and B_g , Eq. (11) and (12), respectively, that imply on the significant reduction of the floor effective weight W, giving higher values for the acceleration according to Eq. (9).

In general, it can be concluded that:

- The fundamental frequencies calculated by the analytical method of the AISC 360-10 code are, most frequently, slightly smaller than numerical fundamental frequencies, configuring a trustworthy analytical simplification for the determination of the floor fundamental frequency;
- Regarding the accelerations, the values obtained by the analytical method were found consistently larger than those by the computational model, showing that the AISC 360-10 formulation presents a reasonable safety margin.

VI. Acknowledgements

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Durability Characteristics of SCC: Influence of Manufacturing Type i.e. Powder Type, VMA Type and Combined Powder and VMA Type

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Abstract- Self-Consolidating Concrete (SCC) often known as self compacting concrete is becoming more widely used in construction in recent years due to its favourable attributes, such as productivity improvements, reduced labour costs, improved work environment and safety and improved product quality. The self consolidating concrete can be obtained by using high powder content or by Viscosity Modifying Agents (VMA), or a combination of both. Keeping in view the possible effect of manufacturing process on the performance of the SCC this study was carried out. Silica Fume (SF) was used as additional powder in powder type and combined powder and VMA type SCC. The fresh properties, strength and durability characteristics were studied. The compressive strength was compared to study the strength and durability relations. The chloride ingress, sorptivity and resistance to acid attack were investigated to assess the durability performance. In all the tests implied in this investigation combined powder and VMA type SCC exhibited the excellent performance among all the three categories of the SCC.

Keywords: SCC, powder, silica fume, durability of SCC.

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Abstract- Self-Consolidating Concrete (SCC) often known as self compacting concrete is becoming more widely used in construction in recent years due to its favourable attributes, such as productivity improvements, reduced labour costs, improved work environment and safety and improved product quality. The self consolidating concrete can be obtained by using high powder content or by Viscosity Modifying Agents (VMA), or a combination of both. Keeping in view the possible effect of manufacturing process on the performance of the SCC this study was carried out. Silica Fume (SF) was used as additional powder in powder type and combined powder and VMA type SCC. The fresh properties, strength and durability characteristics were studied. The compressive strength was compared to study the strength and durability relations. The chloride ingress, sorptivity and resistance to acid attack were investigated to assess the durability performance. In all the tests implied in this investigation combined powder and VMA type SCC exhibited the excellent performance among all the three categories of the SCC.

Keywords: SCC, powder, silica fume, durability of SCC.

I. Introduction

According to the American Concrete Institute (ACI) Committee 237(2007), SCC is defined as 'a highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation'. Another definition according to the European Guidelines for SCC (EFNARC 2002) is 'a concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction'.

Due to special requirements for SCC in its fresh state, the procedures for mix proportioning commonly used for normal concretes had to be modified. The SCC mix can be obtained by using high powder content or by Viscosity Modifying Agents (VMA), or a combination of both, in addition to a higher dose of the superplasticiser as compared to ordinary concretes. The mixture proportioning method suggested by Nan Su et al. (2001) has been used in this investigation. This method takes into account the required strength of the SCC. The same has been used to obtain other types of SCC by varying the powder content and cement content so as to obtain required strength. All the mix proportioning methods suggested in the literature deal only with powder type SCC. All the research that has taken place to study durability of SCC considered only the powder type SCC. The influence of manufacturing process i.e. powder type, combined powder and VMA type which is mentioned as combined type SCC hereafter and VMA type SCC on the durability of SCC was however not studied. The effect of manufacturing process does affect the choice of type of SCC in prevailing conditions. Hence it was decided to study the durability through performance of various types of SCC in acid attack, chloride attack and the capillary water absorption. The SCC is more vulnerable to H_2SO_4 than other acidic environments (Al-Tamimi and Sonebi M. 2003). The parameters studied for resistance to acid attack were the loss in strength and mass after immersing the specimens in 3% H_2SO_4 for 90 days. The penetration of chloride ions increases the risk of corrosion in reinforced concrete structures. The depth of chloride ingress was hence measured using colorimetric technique (Stanish K. D. Et al 1997). Kazim Turk et al. (2007) studied the effect of curing regime and pozzolanic admixtures on sorptivity of SCC as one of the durability characteristics of SCC. The capillary water absorption of all categories of SCC was measured in this study with the help of sorptivity test.

II. Experimental Programme

a) Materials

i. *Cement*

Ordinary Portland cement of grade 53 conforming to the IS 8112:1989 with specific gravity 3.12 was used for all the mixes.

ii. *Fine Aggregate*

River sand conforming to zone II of IS 383:1970 having a specific gravity 2.52 was used as fine aggregate (F A).

iii. *Coarse Aggregate*

The coarse aggregate (C A) had a maximum size of 16 mm. The fractions of coarse aggregate used were: 10 percent of it was passing through 10 mm IS sieve and retaining on 4.75 mm IS sieve, 60 percent of it

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was passing through 12.5 mm IS sieve and retaining on 10 mm IS sieve and 30 percent of it was passing through 16 mm IS sieve and retaining on 12.5 mm IS sieve. The specific gravity of the coarse aggregate was 2.67.

iv. *Superplasticiser*

The superplasticiser used in this study was Glenium B233 procured from BASF. It is based on modified polycarboxylic ether. It complies with ASTM C494 Types F and IS 9103:1999.

v. *Viscosity Modifying Agent*

The Viscosity Modifying Agent reduces the possibility of segregation and becomes essential ingredient when adequate paste volume is not present in the SCC. The VMA used to manufacture VMA type of SCC and combined type SCC was Glenium Stream 2 procured from BASF.

vi. *Water*

Clean potable water available in the laboratory was used for mixing the concrete.

vii. *Silica Fume*

Silica fume imparts very good improvement to rheological, mechanical and chemical properties. It improves the durability of the concrete by reinforcing the microstructure through filler effect and reduces segregation and bleeding. It also helps in achieving high early strength. Silica fume of specific gravity 2.2 was used in this study. Chemical composition of silica fume is given in table 1. Silica fume was obtained from ELKEM India, Mumbai.

Table 1 : Chemical composition of Silica fume

Sr. No.	Constituents	Quantity (%)
1.	SiO_2	91.03
2.	Al_2O_3	0.39
3.	Fe_2O_3	2.11
4.	CaO	1.5
5.	LOI	4.05

III. Mix Proportioning of Self Consolidating Concrete

Three types of SCCs viz. powder type, VMA type and combined type were manufactured for three strength categories M25, M35 and M45. Method suggested by Nan Su et al (2001) was referred for obtaining powder type SCC. Silica fume was used as filler in this type. For obtaining combined type SCC the filler content was almost halved. The modifications were necessary for each SCC mix to achieve the self consolidating properties as well as required strength. For obtaining VMA type SCC the cement content was increased as compared to the same in other two types of SCC mixes keeping all other ingredients in same proportions in each strength category. The final mixture proportions are given in Table 2.

Table 2 : Mix proportions in kg per cubic meter of SCC

Type of SCC	Specimen	Grade	Cement	S. F.	F A	C A	Water	SP	VMA
Powder type	AS1	M25	258	205	960	813	208	5.74	0
	AS2	M35	311	166	960	813	190	7.87	0
	AS3	M45	357	125	960	813	165	8.96	0
Combined powder & VMA type	BS1	M25	258	102	960	813	162	5.04	0.108
	BS2	M35	311	83	960	813	156	7.36	0.079
	BS3	M45	357	63	960	813	147	8.06	0.084
VMA type	CV1	M25	305	0	960	813	137	6.1	0.183
	CV2	M35	348	0	960	813	139	8.0	0.209
	CV3	M45	393	0	960	813	137	10.21	0.235

IV. Specimen Preparation

The mixing of all mixes was done in pan type of concrete mixer. The powder and the aggregates were mixed in dry state for one minute then 70% of calculated water was added in the mixer which was then mixed for 3 minutes. Then 30% of water was mixed with the super plasticizer and added in the powder type concrete mixes. Wherein for VMA type and combined type SCC mixes, out of remaining 30% water 20% was mixed with super-plasticiser and poured in the mixer and mixed for three minutes. Finally VMA was added in the last 10% of water and then poured in the mixer and mixed for one minute. During mixing process the doses of superplasticiser and VMA were adjusted to achieve required plasticity and viscosity of each mix.

Then every mix was checked for self consolidating ability by slump flow test, v-funnel test and L-box test. The results of fresh concrete properties of all the mixes satisfying the self compacting ability have been shown in Table 4. The EFNARC specifications for self consolidating ability have been shown in Table 3. These mixes exhibited horizontal slump flow without signs of bleeding even at the outer boundary. This visual inspection confirmed the segregation resistance of the SCC mixes. After checking the self consolidating ability of the mix it was poured into the cube moulds of different sizes. The moulds were covered with wet gunny bags for 24 hours after casting and the specimens were then immersed in water for curing after demoulding. Cubes of 150×150×150mm were cast for test of compressive strength. All durability tests were performed on 100×100×100mm cube specimens.

Table 3 : Requirements of self consolidating ability as per the EFNARC specifications

Method	Properties	Range of values
Slump flow	Filling ability	650-800 mm
V-funnel	Viscosity	6-12 sec.
L-box ratio	Passing ability	0.8-1.0

a) Test Procedure

i. *Compressive Strength*

Cube specimens of size 150×150×150mm were tested for average compressive strength at 3 days, 7 days and 28 days according to IS 516. Three specimens were tested per test.

ii. *Durability Tests*

The durability tests were carried out on cube specimens after 28 days of curing. For each test of each mix three specimens were tested and average of the three has been shown.

iii. *Sorptivity Test*

The test for water absorption by capillary action (sorptivity) was carried out to determine the sorptivity coefficient of concrete specimens which were preconditioned in oven at 105^{0}C for 24 hr. and then allowed to cool down at room temperature for 24hr to achieve a constant moisture level. Then, four sides of the concrete specimens were sealed by electrical tape keeping two opposite sides exposed to avoid evaporative effect as well as to maintain uniaxial water flow during the test. Before locating the specimens on water, their initial weight was recorded. One face of specimen was in contact with water. Only 5mm depth of the specimen was submerged in water. The water absorption at predefined intervals was noted by taking weight. Procedure was repeated, consecutively at various time intervals like 15 min., 30 min., 1 hr, 2 hr, 4 hr, 6 hr, 24 hr, 48 hr and 72 hr. Sorptivity coefficient was calculated by the following expression. It is given by the slope of the sorptivity curve when it gets stabilised.

$S= (Q/A)/\sqrt{t}$

Where,

S = Sorptivity (cm/s$^{1/2}$)

Q = Vol. of water absorbed in cm^3

A = Surface area in contact with water in cm^2

t = the time (s)

b) Acid Attack

As reported by Girardi & Di Maggio (2011) sulphuric acid first attacks the calcium hydroxide, and then C–S–H too as soon as portlandite is no longer available, making the calcium hydroxide form gypsum and the calcium silicate hydrate (C–S–H) form both anhydrous gypsum and an incoherent mass of hydrated silicate. In a second step, calcium aluminate hydrate reacts with the sodium sulphate ions from the sulphuric acid, forming ettringite (3CaO_Al2O3_3CaSO4_32H2O). Ettringite having higher volume causes increase in volume of concrete and even the disrupture of concrete. The percentage loss in mass and compressive strength was thus determined for the test specimens of both type of SCC in following manner. The cube specimens after curing in water for 28 days were taken out of curing tank. The specimens were then placed in solution of 3% H_2SO_4. The pH of the solution was regularly monitored and adjusted to keep it constant. The consumed solution was replaced with freshly prepared solution every week. The cubes were immersed in acid for 90 days and the assessment of performance in acid attack was made from

- Mass loss
- % loss in compressive strength.

c) The Chloride Ingress

In the presence of chloride ions the steel reinforcing bars are more prone to corrosion. The test for chloride ingress was hence carried out in this study. A colorimetric technique was adopted. The cube specimens after 28 days curing were immersed in 3% NaCl solution for another 28 days representing the exposure to saline or sea water. The cubes were then taken out of chloride solution and split. The $AgNO_3$ solution was sprayed on the exposed area after splitting. When silver nitrate solution was sprayed on a concrete containing chloride ions, a chemical reaction occurred. The chlorides bind with the silver to produce silver chloride, a whitish substance. In the absence of chlorides, the silver instead bonds with the hydroxides present in the concrete creating a brownish colour. A whitish colour at the border of specimen shows the depth of penetration. It was measured with the help of Vernier Calliper along all four borders of each specimen and the average was taken. The depth of chloride ingress measured by this method is only a quantitative measure and does not give any idea about the chloride ion concentration.

V. Results and Discussions

a) Fresh Properties

The test results of fresh properties have been shown in Table 4. It can be observed that the powder type as well as combined type SCC has shown better results than VMA type in fresh state. The slump value of

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VMA type ranged between 665 to 682 mm while the same for other two types ranged between 664 to 712mm. There was no significance difference in V-funnel time. The L-Box ratio of VMA type was between 0.81 and 0.85 and for other two types it was between 0.88 and 0.93. The better performance of powder type and combined type SCC in fresh state can be attributed to of higher powder content of these mixes.

b) Compressive Strength

The compressive strength results of all the mixes of SCC have been shown in Figure 1. and table 5.

Table 4 : Fresh properties of SCC

Type of SCC	Specimen Type	Slump Flow (mm)	V-Funnel (sec)	L-Box h^1/h^2
Powder type	AS1	705	9.2	0.93
	AS2	689	10.1	0.91
	AS3	664	11	0.88
Combined type	BS1	712	9.5	0.91
	BS2	684	10.7	0.89
	BS3	692	10.3	0.93
VMA type	CV1	674	10.6	0.83
	CV2	665	11.2	0.81
	CV3	682	10	0.85

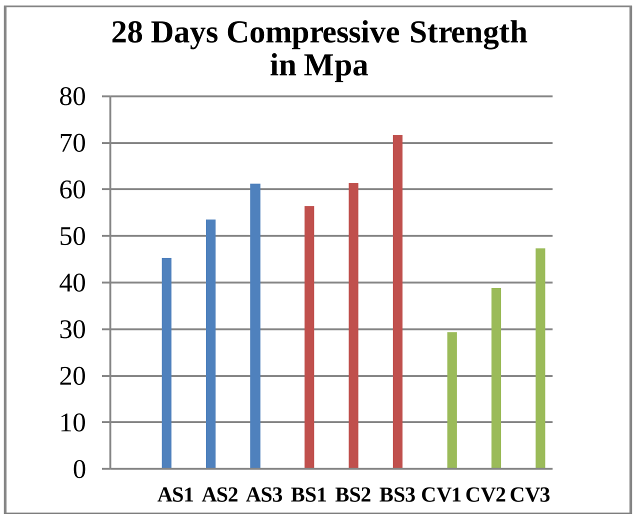

Figure 1

The compressive strength of VMA type of mixes for all grades was just achieved. The powder type mixes showed much better strength than VMA type and the combined powder and VMA type mixes showed maximum strength for all grades. In case of M25 grade mixes the strength achieved by powder type i.e. AS1 mix was 1.54 times the same for VMA mix i.e. CV1 and in M45 category the strength of AS3 was 1.29 times the strength of CV3. The combined type i.e. BS1 mix had compressive strength 1.91 times CV1 and BS3 had compressive strength 1.51 times the strength of VMA3. Both powder type and the combined type SCCs had shown higher strength because of dense structure caused by the higher powder content and pozzolanic reactivity of silica fume. The content of silica fume was more in powder type mixes than the combined type mixes and still their strength was slightly less, this can be due to more quantity of unhydrated silica fume particles remained at the end of 28 days of curing.

Table 5 : Results of strength and durability tests

Type of SCC	Specimen	Grade	Compressive strength in Mpa	Sorptivity cm/√sec	% mass loss in 3% H_2SO_4	% loss in comp strength in 3% H_2SO_4	Chloride ingress in mm
Powder type	AS1	M25	45.31	0.00283	1.42	4.78	1.8
	AS2	M35	53.45	0.00268	1.33	4.51	1.5
	AS3	M45	61.22	0.00253	1.22	3.93	0.9
Combined type	BS1	M25	56.35	0.00253	1.32	4.35	1.6
	BS2	M35	61.32	0.00239	1.26	4.13	1.2
	BS3	M45	71.67	0.00164	1.025	3.6	0.8
VMA type	CV1	M25	29.38	0.00449	2.81	17.13	24
	CV2	M35	38.84	0.00395	2.59	14.71	17.4
	CV3	M45	47.32	0.00354	2.21	12.46	10.8

c) *Durability Results*

i. *Sorptivity*

The sorptivity coefficient of combined powder and VMA type SCCs was least among all the types of SCCs. It was 11% to 36% less than powder type SCCs and 44% to 54% less than VMA type SCCs. The performance of all the SCCs in sorptivity test is almost similar to that in compressive strength tests. The results have been shown in Table 5 and Fig2.

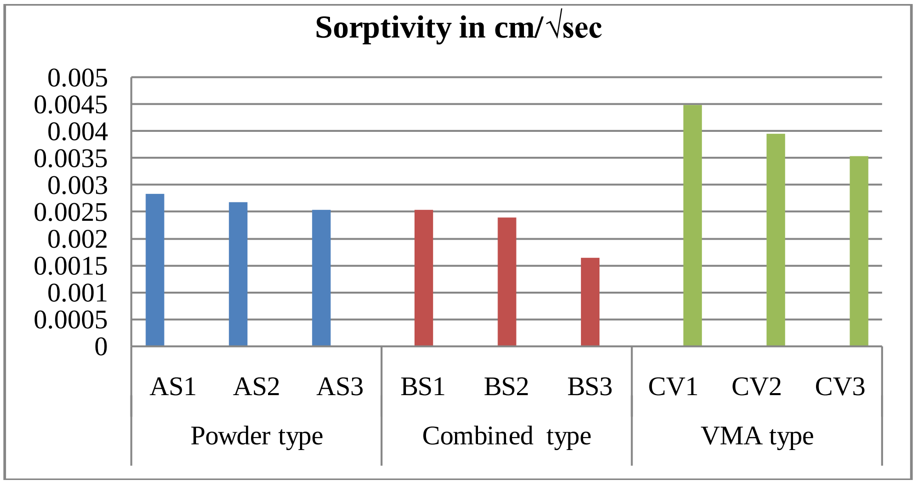

Figure 2

d) *Acid Attack*

The performance of all the types of SCCs was evaluated on the basis of percentage mass loss and percentage loss in compressive strength. The VMA type of SCC was found to be most vulnerable to acid attack. The resistance of powder type SCCs was better and of combined type was the best in all strength categories. The mass loss was almost half in case of powder type mixes as compared to VMA type and the loss in compressive strength was in the range of only 28 to 31% to that of VMA type. The mass loss in case of combined type was in the range of 46 to 47% of that in VMA type mixes and the loss in compressive strength was only 25 to 29% of that in VMA type mixes. The better performance of powder and combined type mixes should be attributed to less permeability than VMA type mixes. The results have been shown in Table 5 and figure 3.

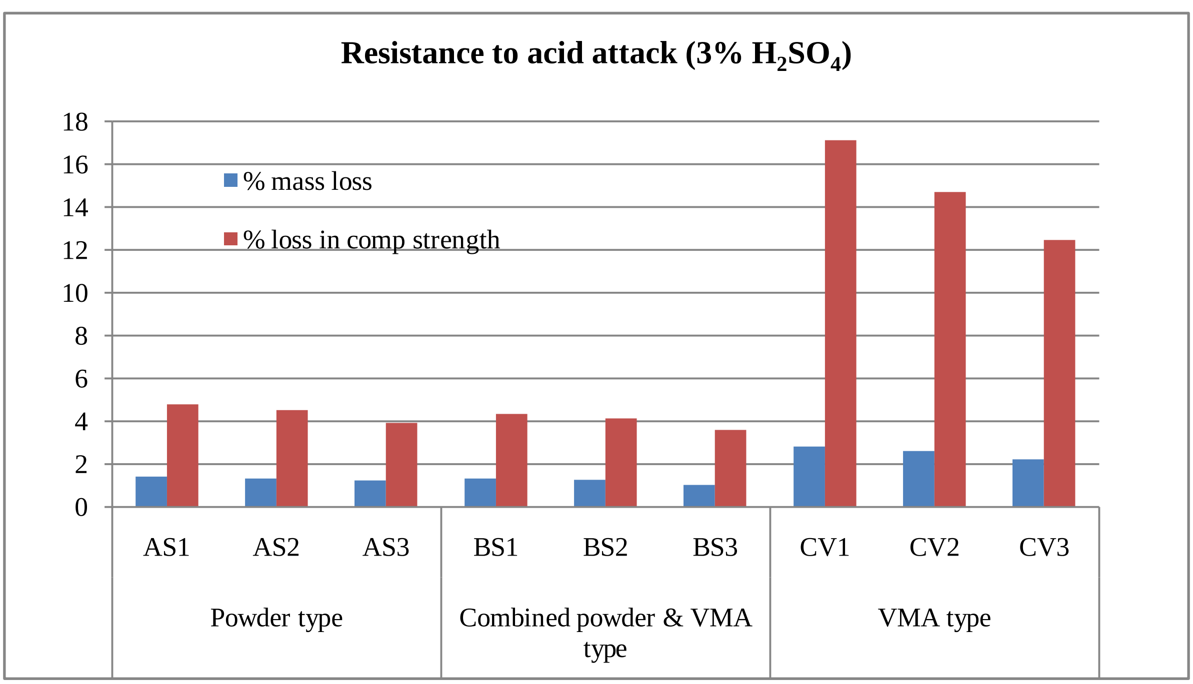

Figure 3

VI. Chloride Ingress

The combined type of SCC mixes showed least ingress of chlorides. The chloride ingress was very small in both powder type and combined type as compared with that in VMA type SCCs. It was only in the range of 0.8 to 1.6 mm in combined type, 0.9 to 1.8 mm in powder type and as large as 10.8 to 24 mm in VMA type SCCs. The large difference of chloride ingress in VMA type and other two types of SCCs must be due to dense structure and improved microstructure in the powder and combined type SCCs. The pozzolanic effect and very fine size of silica fume particles must have played the important role in exhibiting excellent durability characteristics. The results have been shown in Table 5.

VII. Conclusions

The combined powder and VMA type SCCs produced highest strength, excellent resistance to acid attack, least sorptivity and least amount of chloride ingress. Though there was marginal difference in durability performance of powder type SCCs and combined type SCCs the difference in strength was significant. The combined powder type SCC is hence concluded to be the best type of SCC for any strength category. The reasons for the best performance may be the finest size of filler particles, less amount of unhydrated particles, better microstructure of hydrated products and very dense structure of SCC produced. EFNARC (2002) (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self-compacting concrete, Hampshire, U.K.

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Suitability of Selected Bangladesh Sands for the Determination of In-Situ Soil Density

By M. A. Bashar & A. B. M. M. Rashid
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Abstract- Usually Ottawa sand is used to find out in-situ density of soil by sand replacement method. Ottawa sand is very expensive and it is always imported from abroad. To avoid these difficulties the quality and suitability of locally available sand in and around Khulna district in Bangladesh in lieu of Ottawa sand were assessed for determining in-situ density using sand replacement method. Five samples of sand named by Sylhet sand, Kushtia sand, Fultala sand, Bogjhuri sand and Mongla sand were collected from nearby business centers. Original sand and some graded sands of each sample were under investigation to ascertain their suitability of use in lieu of Ottawa sand in determining in situ soil density. Five gradations were considered and those were (i) passing #16 and retained in #30, (ii) passing #30 and retained in #40, (iii) passing #40 and retained in #50, (iv) passing #30 and retained in #50 sieve and (v) passing #50 and retained in #100 sieve . Each of the original samples has been characterized by determining its index properties, grain size distribution. Specific gravity and density were determined for each sample of original and graded sands. These properties were compared with those recommended by ASTM (1989) for selecting suitable sand in sand replacement method.

Keywords: in-situ density, ottawa sand, bangladesh sands, grading of sand, sand replacement method.

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SUITABILITYOFSELECTEDBANGLADESHSANDSFORTHEDETERMINATIONOFINSITUSOILDENSITY

Strictly as per the compliance and regulations of :

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From this study it was found that original sands of all selected places in Bangladesh did not satisfy the ASTM (1989) criteria of Ottawa sand. In case of graded sands, Sylhet sand satisfied all the required ASTM criteria for four gradations except the gradation passing from #50 to #100 sieve, while Kushtia and Fultala sands satisfied fully for three gradations except the gradations passing from #16 to #30 sieve and passing from #50 to #100 sieve. Bogjhuri and Mongla sands did not satisfy all criteria. So, the graded sands that satisfy the criteria of Ottawa sand as mentioned in investigation may be used in sand replacement method in lieu of costly Ottawa sand.

Keywords: in-situ density, ottawa sand, bangladesh sands, grading of sand, sand replacement method.

I. Introduction

Without measurement of in-situ density one cannot understand about the bearing capacity and stability of soil. In situ soil density can be measured by various methods. In the present study, only measurement of in-situ density of sandy soil was under consideration. Among all the methods, sand replacement method may be used for all types of soil. However to measure in-situ density by sand replacement method, Ottawa sand is used according to ASTM (1989). Ottawa sand consists of pure siliceous materials and is practically all of one size and white in colour. The specification of this test requires that the sand must be uniformly graded and rounded in shape to ascertain its free fall. In Bangladesh, sands are available in abundance and it is expected that some of them might meet the specification requirements for density determination. If so the use of local sand would be less costly and may be used instead of expensive Ottawa sand due to its nominal cost, Furthermore, the local sand can be afforded to left in place after performing the test which will shorten the testing time.

Ottawa sand is collected from abroad and it is very costly. From this point of view, this study was to ascertain the suitability of locally available less costly sands in lieu of costly Ottawa sand.

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II. Criteria of Sand to be Used

According to ASTM (1989) major required criteria of Sand to be used in sand replacement method are:

a) Sand should be clean, dry, uniform, uncemented, durable and free flowing.
b) Any gradation may be used that has uniformity coefficient ($C_u = D_{60} / D_{10}$) less than 2.0, a maximum particle size less than 2.00 mm (No. 10 sieve) and less than 3 % by weight passing 250 μm (No. 60 sieve).
c) Uniform sand is needed to prevent segregation during handling, storage and use. Sand free of fines and fine sand particles is needed to prevent significant bulk density changes with normal daily changes in atmospheric humidity.
d) Sand comprised of durable, natural surrounded or rounded particles is desirable. Crushed sand or sand having angular particles may not be free flowing.
e) In selecting sand from a potential source, five separate bulk density determinations shall be made on each container or bag of sand. To be acceptable sand, the variation between any determination and average shall not be greater than 1% of the average.
f) Before using sand in density determinations it shall be dried. Then allowed to reach an air dried state in the general location where it is to be used.

g) Sand shall not be reused without removing any contaminating soil, checking the gradation and drying.

h) Bulk density tests shall be made at intervals not exceeding 14 days, always after any significant changes in atmospheric humidity, before reusing and before using a new batch from a previously approved supplier. To determine whether a material is uniformly graded, Hazen (1892) proposed the equation $C_u = D_{60} / D_{10}$. For all Practical purposes the value of Cu < 5 can be considered for uniformly graded granular soils (Murthy, 1996).

III. Selection of Sand and Methodology

For suitability of using locally available sands for determining in-situ soil density, five types of sands were selected, namely, Sylhet sand, Kushtia sand, Fultala sand, Bogjhuri sand and Mongla sand. The sand samples were collected from nearby locations in Bangladesh as mentioned in Table 1.

Each of the collected samples was characterized by determining their index properties. In the laboratory grain size analysis and specific gravity test for each of the samples were performed according to standard procedure (Josheph, 1992; Lambe, 1993). In addition to original sands, some graded sands of these locations were also selected to ascertain the suitability of using in sand replacement method. Each sample was air dried and then graded with ASTM standard set of sieves containing #16, #30, #40, #50. In case of all the graded sands in addition to Ottawa sand, density was also measured in the laboratory. The following gradations of sands are selected in this study.

a) Sample passing sieve #16 and retained in sieve #30

b) Sample passing sieve #30 and retained in sieve #40

c) Sample passing sieve #40 and retained in sieve #50

d) Sample passing sieve #30 and retained in sieve #50

e) Sample passing sieve #50 and retained in sieve #100

Table 1 : Types of sands and designations

Sl. No.	Types of sand	Sample designation	Place of collection
1.	Sylhet	S-1	*Nowapara, Jessore*
2.	Sylhet	S-2	Patkelghata, Satkhira
3.	Sylhet	S-3	Rupshaghat, Khulna
4.	Kushtia	K-1	Nowapara, Jessore
5.	Kushtia	K-2	Nogorghat Railigate, Khulna
6.	Kushtia	K-3	Daulatpur, Khulna
7.	Fultala	F-1	Damodar, Fultala, Khulna
8.	Bagjhuri	B-1	Cable-ghat, Shiramoni, Khulna
9.	Mongla	M-1	Mongla, Bagerhat

IV. Laboratory Investigation

From grain size distribution analysis, D_{10} (particle size against 10% finer of the sample), D_{60} (particle size against 60% finer of the sample), FM (fineness modulus) and Cu (uniformity coefficient) were determined. Specific gravity of each collected sand sample was also determined. The index properties of original sands are shown in Table 2 and index properties of graded sands are shown in Tables 3 and 4.

Table 2 : Index properties of original sands

Sl. no.	Sample Designation	D_{10}	D_{60}	C_u	F.M.	G_s	Max. Particle Size (mm)	% Passing through 250 µm
1.	S-1	0.22	0.64	2.91	2.39	2.69	2.36	10.00
2.	S-2	0.23	0.72	3.13	2.56	2.71	2.31	8.00
3.	S-3	0.23	0.78	3.39	2.61	2.66	2.36	4.00
4.	K-1	0.12	0.32	2.67	1.32	2.72	1.52	13.00
5.	K-2	0.14	0.36	2.57	1.52	2.70	1.24	14.00
6.	K-3	0.16	0.47	2.56	1.74	2.72	1.50	9.00
7.	F-1	0.14	0.37	2.64	1.55	2.86	0.84	23.00
8.	B-1	0.13	0.29	2.23	1.27	2.72	0.76	82.00
9.	M-1	0.16	0.27	1.69	1.08	2.71	0.70	55.00

Table 3 : Index properties of graded Sylhet sands (S-1)

Sl. No.	*Gradation*	D_{10}	D_{60}	C_u	Max. Particle (mm)	% Passing through 250 µm
1.	(-) No. 16 & (+) No.30	0.65	0.86	1.323	1.20	0.00
2.	(-) No. 30 & (+) No.40	0.45	0.56	1.244	0.62	0.00
3.	(-) No. 40 & (+) No.50	0.30	0.40	1.330	0.40	0.00
4.	(-) No. 50 & (+) No.100	0.18	0.25	1.390	0.32	66.00

N.B.: (-) means passing through sieve and (+) means retaining on sieve

Table 4 : Index properties of all sands of grade (-) No. 30 & (+) No. 50

Sl. No.	Sample Designation	D_{10}	D_{60}	C_u	Max. Particle Size (mm)	% Passing through 250 µm
1.	S-1	0.31	0.45	1.45	0.40	0.00
2.	S-2	0.32	0.45	1.41	0.40	0.00
3.	S-3	0.34	0.46	1.35	0.40	0.00
4.	K-1	0.32	0.46	1.44	0.40	0.00
5.	K-2	0.30	0.42	1.40	0.40	0.00
6.	K-3	0.33	0.45	1.36	0.40	0.00
7.	F-1	0.32	0.42	1.31	0.40	0.00
8.	B-1	0.31	0.40	1.29	0.40	0.00
9.	M-1	0.30	0.35	1.17	0.40	0.00

Bulk density test on graded Ottawa sand (O-1) was performed in the laboratory by sand replacement method and the results are shown in Table 5. Bulk densities of all graded sands were also measured in the laboratory by using same method. The results are also shown in Table 5. Five separate density tests were performed on each graded sand. From the results it can be observed that the first four grades of Sylhet sand in Table 5 fulfill the criteria mentioned by ASTM (1989).

Table 5 : Density of Ottawa and graded sands

Sample Designation	Density (gm/cm^3)				
	(-) No. 16 & (+) No. 30	(-) No. 30 & (+) No. 40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
O-1	1.545	1.528	1.510	1.498	1.520
S-1	1.323	1.228	1.226	1.248	1.246
S-2	1.324	1.226	1.225	1.256	1.244
S-3	1.321	1.235	1.226	1.264	1.251
K-1	1.323	1.336	1.335	1.333	1.332
K-2	1.270	1.309	1.284	1.320	1.276
K-3	1.305	1.266	1.264	1.266	1.260
F-1	1.321	1.235	1.226	1.263	1.251
B-1	--	1.215	1.203	1.091	1.244
M-1	--	--	1.164	1.237	1.230

N.B.: (-) means passing through sieve and (+) means retaining on sieve

V. Results and Discussions

a) *Analysis on Grain Size Distribution and Specific Gravity*

In Table 2 average F.M. values of Sylhet, Kushtia and Fultala sands are exhibited as 2.52, 1.53 and 1.55 respectively. In case of Bogjhuri and Mongla sands, F.M. values are exhibited as 1.27 and 1.08 respectively which can be considered as fine sand in comparison with Sylhet, Kushtia and Fultala sands. From Table 2 it can also be observed that except Mongla sand the uniformity coefficient, Cu of all other original sands were greater than 2.0, while it can be observed from Tables 3 to 4, the values of Cu are less than 2.0 for all the graded sands. The ASTM (1989) recommended that the value of Cu for the sand used in sand replacement method should be less than 2.0.

From Tables 2 to 4 it can be observed that except the original Sylhet sand, maximum particle size for all types of collected sands as well as the graded sands were less than 2.00 mm which satisfy the recommended value of ASTM (1989). In case of original Sylhet sand maximum particle size varies from 2.31 mm to 2.36 mm which does not satisfy the criteria.

ASTM (1989) recommends that less than 3% by weight of sand should pass through 250*µ*m. From Table

2 it can be observed that in case of original sands this value varies form 4% to 82%. Table 3 shows that 66% by weight passes through 250μm in case of graded sands of passing No. 50 sieve and retained on No. 100 sieve, while 0% by weight passes through 250μm in case of all other graded sands. So all the graded sands of passing No. 50 sieve and retained on No. 100 sieve including all original samples fail to satisfy the ASTM (1989) criteria. Table 4 shows that all the graded sands passing through No. 30 sieve and retained on No. 50 sieve recommend the criteria.

In first four selected grades of Sylhet sand in Table 5, the maximum variation of measured density was less than 1% from mean which is not desirable. In case of original Sylhet sand it was observed that this sand is not free flowing and uniform but in case of graded Sylhet sand, this quality improved significantly.

b) Density Analysis of Sand

From Table 5 it is observed that for any particular grade of Ottawa sand, the bulk density is almost same in each determination. Bulk density of graded Sylhet, Kushtia, Fultala, Bogjhuri and Mongla sands are also shown in Table 5. From Table 5 it is observed that the bulk density differs with the different locations for each grade.

In case of Bogjhuri and Mongla sands it is observed that the bulk density of any grade differs significantly from that of Ottawa. Moreover, it is found that these two types of sand are fine for which sufficient coarse grade sample could not be found easily.

From Table 5 it is observed that the bulk densities of Sylhet Sand and Kushtia Sand differ significantly in compared with that of Ottawa sand. In case of graded Sylhet sand it is observed that the bulk density differs significantly from grade passing No. 16 sieve and retained on No. 30 sieve with other grades. However in case of graded Kushtia sand it is observed that the variations of bulk densities of various grades and mixed grades do not differ substantially.

In first four selected grades of Sylhet sand in Table 5, the maximum variation of measured density was less than 1% from mean for three Sylhet sands (S-1, S-2, S-3), while Kushtia sand of 2nd, 3rd and 4th grades in Table 5 showed the maximum variation in measured density was less than 1% from mean for three sands. In case of Fultala sand, 2nd, 3rd and 4th grades in Table 5, this variation was less than 1%.

VI. Conclusions

Based on this study, the main findings have been outlined into following sections:

a) In the determination of in-situ density the following four types of graded Sylhet sands are found to be suitable:

- Sand passing #16 sieve and retained in #30 sieve.
- Sand passing #30 sieve and retained in #40 sieve.
- Sand passing #40 sieve and retained in #50 sieve.
- Sand passing #30 sieve and retained in #50 sieve.

b) The following three types of graded Kushtia Sands are also found to be suitable for determining the in-situ soil density by sand replacement method:

- Sand passing #30 sieve and retained in #40 sieve.
- Sand passing #40 sieve and retained in #50 sieve.
- Sand passing #30 sieve and retained in #50 sieve.

c) The following three types of Graded Fultala Sands are also found to be suitable for determining the in-situ soil density by sand replacement method:

- Sand passing #30 sieve and retained in #40 sieve.
- Sand passing #40 sieve and retained in #50 sieve.
- Sand passing #30 sieve and retained in #50 sieve.

The types of sand mentioned in above three sections [(a), (b) and (c)] fulfill all the criteria recommended by the ASTM (1989) for determination of in-situ soil density.

d) Other sands including original Sylhet and Kushtia sands did not satisfy the required criteria of ASTM (1989).

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Systems Dynamics Simulation Modeling of Transit Oriented Land use Development of a Rail Corridor in Chennai

By Mrs. M. Vijayalakshmi & Dr. G. Umadevi

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Abstract- The growing concern of rapid increase in urban population and vehicular growth culminates into emerging of many metropolitan cities. In such areas, spatial distribution of activities warrant, the necessity for travel by appropriate arrangement of sub-systems in tune with the form of urban structure and routes serving it. In Chennai, the present modal split revealed that only 40% of the travel in the City is made by public transport as against a minimum of 70% recommended by the study group or alternative systems of urban transport system. The modal split between bus and train will have to change from 88:12 (2004) to 60:40 (2026). It calls for a strategy reorienting the travel by appropriately manipulating the policies so as to increase the share of Public Transport.

Hence, there is an urgent need to study the land use transport interaction along the suburban rail corridor to increase patronage. The northern region suburban railway line of Chennai Metropolitan Area is taken as the study from Chennai Central to Gummidipoondi. An opinion survey has been conducted during morning and evening peak period to know the opinion of the train passenger, mode used and distance traveled from origin to station and station to destination was collected. It is found that the majority of originating points are within 2.50km from the station locations. Hence, in this study an attempt is made to find the trend of land use disposition in various periods. Land use map prepared by digital image processing methods using ERDAS Imagine 8.7 software, panchromatic aerial photograph, IRS1D, IRS P6 LISS III Digital data. As the assessment of patronage along the corridor involves a large number of complex and dynamic variables suitable simulation software, namely a dynamic package called STELLA is used to develop the model and test the same for various simulations. Application of this model to similar urban area with moderate modifications will prove to be valid. Further, the model can also be extended micro level planning on a zonal basis.

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I. Introduction

Good transportation system plays a vital role in the overall development of a nation's economy particularly in an urban context. The persistent inadequacy of mass transport facilities in the urban areas has forced individuals to use personalized modes. As a result, there is increased growth of vehicles, especially two wheelers and cars in Indian roads. The existing road network is inadequate and deficient to accommodate the growing vehicular population. This leads to congestion, delay and concomitant pollution of all sorts.

Public transport in India can be into two major modes: rail and road. Out of the country's total passenger movement, 80 percent is met by road transport while remaining 20 percent is carried by railways (Kaushik Deb 2002). These calls for urgent measures and an effective way to address this problem. Thus it is necessary to encourage greater use of public transport especially rail transport instead of personalized vehicles. This can be achieved through Transit Oriented Land Use Development (TOD).

II. Land use Transport Interaction

Conventional transport planning involves assessment of travel demand for given set of land use development and prediction for an anticipated set of land use developments. In practice due to high capital costs, neither the projects identified to cater future rail transport demand have been executed, nor the land use developments has occurred as anticipated. One of the main reasons for such failure is lack of proper appreciation of landuse transport interaction (Kumaravelu 2001). Since landuse and transport systems are more dynamic, it is imperative that the land use - transport model needs to be developed to represent dynamic behavior both with its interaction in the urban area.

III. Need for the Study

Urbanization is a perpetual process. Due to urbanization, the kind of development taking place in most of the Indian cities is in an unplanned manner. Huge influx of population from rural to urban areas in terms of social increase and its natural growth have induced greater demand for travel. The population and vehicular population in Indian cities are increasing alarmingly but the road networks in these cities had not been planned to carry the present day traffic. The area occupied by roads and streets in class – I cities in India is only 16.10 percent of the total developed area while the corresponding figure for the USA is 28.19 percent. Apart from this, the inadequate civic and transport

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infrastructure results in traffic congestion and deterioration of urban environment.

In a paper (Arrington Parsons Brinckerhoff 2004) on "Light Rail Transit and Transit Oriented Development" presented an overview of elements of a successful integrated LRT and TOD strategy. Designing development oriented transit and achieving supportive public policy were examined. He even said that "built it and they will come" is a theory i.e. "Building transit first, in the hope development will follow". A successful TOD reinforces both the community and the transit system. At an individual station TOD can increase ridership by 20% to 40% and upto 5% overall at the regional level.

It is estimated that the rail based system will be required in Cities with population more than 2 million and are generally expected to have transport corridors with maximum demand upto 20,000 peak hour peak direction trips (phpdt) (Vinod Sibal and Yash Sachdeva 2001). There is a need to encourage the use of public transport system especially rail transit mode to achieve sustainable development in the long run. Hence an attempt is made in this present research work to study the land use changes, travel patterns along the corridor and to study the operational characteristics and utilization of existing railway line and bus services.

IV. Objectives of the Study

Keeping in view of the necessity of Transit Oriented Development, the objectives of this study have been framed as follows:

- To study the past and present use of land along the rail corridor to detect the changes in land use in order to plan for its optimal use.
- To study the operation of both rail and bus transportation system and understand the existing level of utilization.
- To understand and appreciate the characteristics of the user groups of both rail and bus systems and characteristics of households settled along transit corridor.
- To develop a System Dynamic Simulation model for encouraging Transit Oriented Land Use Development.
- To evaluate relevant policy options relating to land use and transport integration towards optimal utilisation of public transport especially rail, to achieve sustainable development in the long run.

V. Study Methodology

The study methodology is shown in Figure 1. It involves study on Land use changes for various periods using Remote Sensing Analysis and building of System Dynamics Model for various scenario options:

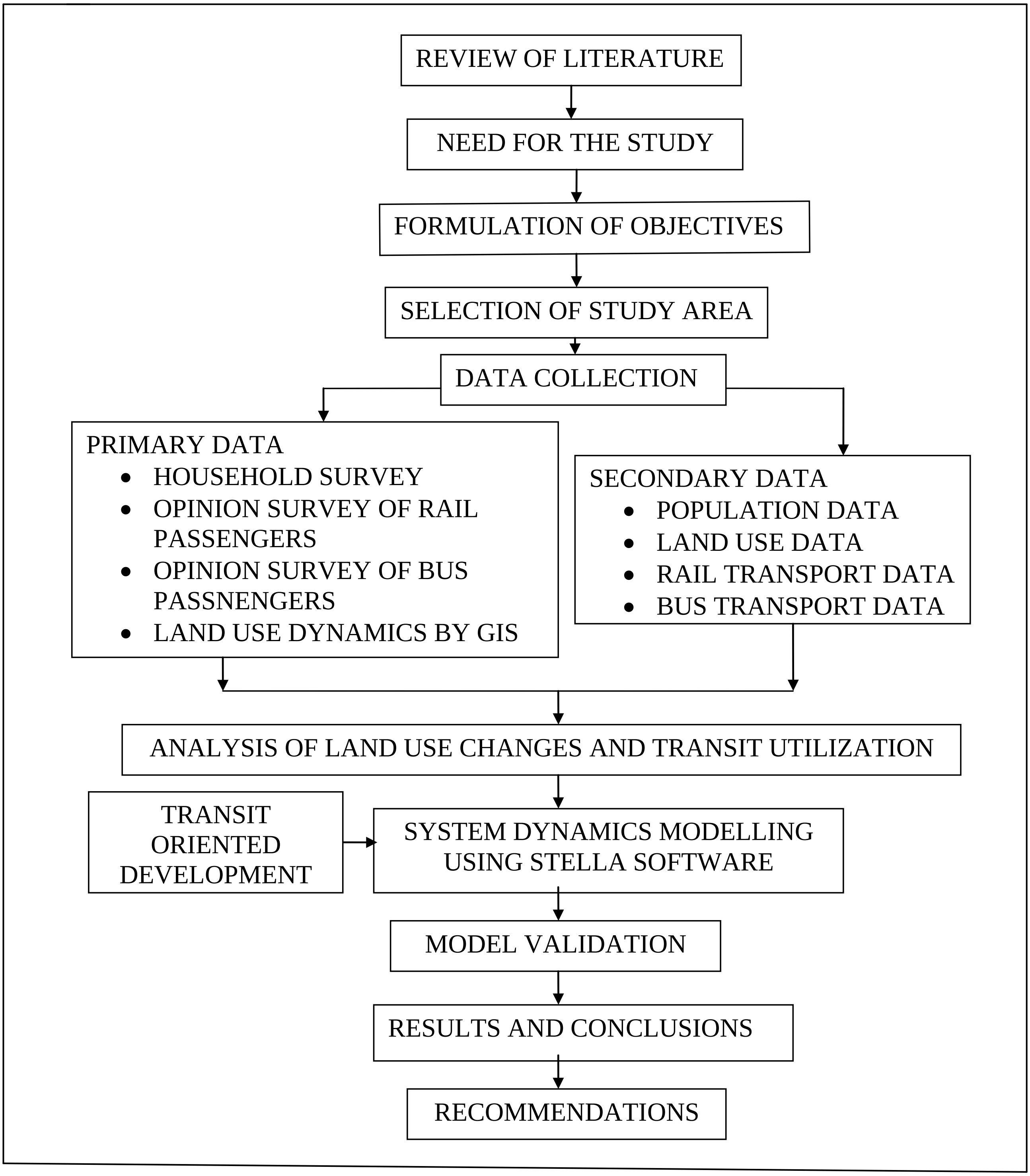

Figure 1 : Study Methodology

VI. Identification and Delineation of Study Area

Chennai Central to Gummidipoondi Corridor has been identified as low patronage one compare to other suburban corridors. The Table 1 gives the characteristics of various stations in suburban corridor.

The influence area of stations was assessed based on a survey of boarding passengers. The questionnaire survey has been conducted during the morning and evening peak hours. The walking distance of passengers was one of the criteria chosen to delineate influence areas. The line up to Chennai City and CMA are taken as segment I and segment II. The analysis of

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the survey data showed that the majority of originating points and destination points are within 1.00km by walk and 2.50km by walk and other personalised and paratransit modes.

VII. Land use Change Detection

A spatial methodology was used for land use change detection. It involved four steps, namely Preparation of land use map, Digitization of land use maps, Integration of classified land use maps, Analysis of land use changes during 1986 to 1996 and 1996 to 2006 and Analysis of land use development along railway line at a distance of 0.50 km, 1.00 km and 2.50 km. These steps are shown in Figure 5.32 and discussed in the following sections. Data used for the land use analysis are namely , Panchromatic Aerial Photograph (1986 on 1: 50,000 scale), Satellite data IRS-1C (1996 on 1:50,000 scale) and Satellite data IRS-P6, and LISS III digital data (2006) were acquired. The survey of India toposheets on 1:50,000 scale were used as a reference data.

VIII. Preparation of Land use Map

Base map on 1:50,000 scale was prepared from the Survey of India toposheets on the same scale. After scanning all imageries, land use classification was prepared. Land use map was prepared by Digital Image Processing method using Erdas Imagine 8.7 Software.

Table 1 : Characteristics of various Stations in the study corridor

Sl. No.	Name of stations	Distance in km	Inter-station distance in km
1	Chennai central	0.00	0.00
2	Basin Bridge	2.22	2.22
3	Korukkupet	2.93	0.71
4	Tondiarpet	4.08	1.15
5	Tondiarpet Marshalling Yard	5.73	1.65
6	Tiruvottiyur	7.81	2.08
7	Wimco Nagar	10.31	2.5
8	Kathivakkam	13.33	3.02
9	Ennore	14.88	1.55
10	Attipattu Pudunagar	19.1	4.22
11	Nandiyambakkam	20.88	1.78
12	Attipattu	22.16	1.28
13	Minjur	24.78	2.62
14	Anuppampattu	28.79	4.01
15	Ponneri	33.48	4.69
16	Kavaraipettai	40.16	6.68
17	Gummidipoondi	46.08	5.92

Source: Southern Railways

Supervised classification was applied to derive the landform in the study area. The classification was residential, commercial, institutional, industrial, agricultural, waste land, water bodies, vacant land and others. Based on this category, land use maps were prepared through visual interpretation of imageries.

a) Digitization of Land use Maps

Visual interpretation of base maps, and land use maps were digitized in ArcGIS 9.1 software and edited in Arc Tool Box in GIS environment. After digitizing the study area, different themes like residential, commercial, institutional, industrial (all polygon themes) and the corresponding land uses were digitized from the land use data obtained from the remote sensing satellite. The rail station theme is created to indicate the location of the rail station in the area. The land use themes are created to represent the type of land uses in and around the rail stations.

b) Assessment on Changes in Land Use

Based on the aggregated data, land use maps of different years i.e., 1986, 1996 and 2006 were prepared and the land use maps are presented respectively in fig.2, fig.3 and fig.4. It could be observed from all the three maps that the substantial amount of shift from residential to commercial. These changes are represented in the form of a schematic diagram in figures. The land use development and growth pattern along the development corridor clearly are depicted in various periods. Using GIS package in ARC/INFO environment, land use information was integrated for generating maps for these years. A comparison of maps would reveal enormous changes in the pattern of land use.

From the analysis, it is observed that most of the agricultural, water bodies, vacant land and waste lands are converted to residential areas due to the pressure of urbanization. The area enclosed near rail corridor is very densely populated. The urban sprawl is extending heavily to the Northern side along the Chennai Central to Gummidipoondi suburban rail corridor.

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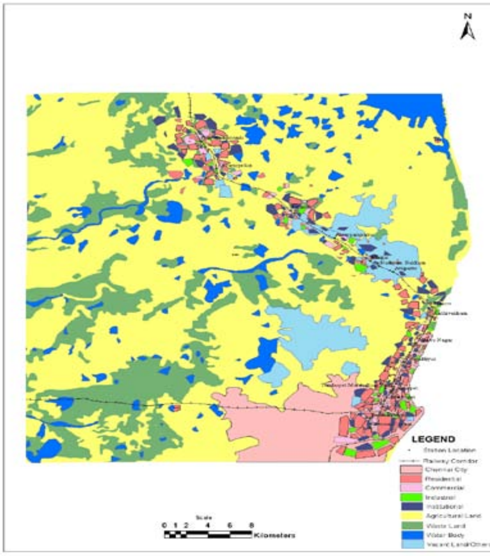

Figure 2 : Extent of Land Use in 1986

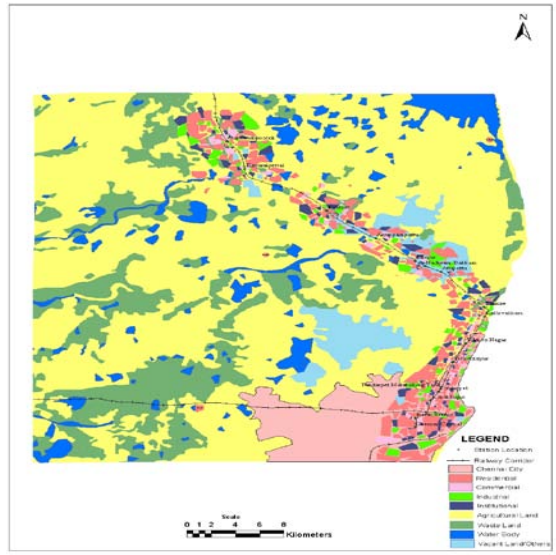

Figure 3 : Extent of Land Use in 1996

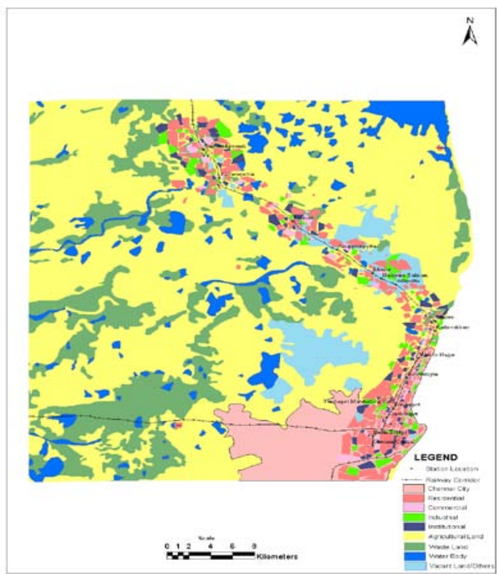

Figure 4 : Extent of Land Use in 2006

Table 2 : Details on Various Land Uses for Three Time Period

Land Use Category	Area (sq.km.)	Percentage of CMA	Area (sq.km.)	Percentage of CMA	Area (Sq.km.)	Percentage of CMA
Year	1986		1996		2006	
Residential	29.64	11.62	42.60	16.71	53.55	21.00
Commercial	4.97	1.95	5.32	2.09	6.51	2.55
Institutional	6.59	2.58	7.47	2.93	8.72	3.42
Industrial	14.33	5.62	15.86	6.22	18.16	7.12
Waste land	16.72	6.56	17.02	6.67	15.33	6.01
Water bodies	22.68	8.89	20.67	8.11	17.06	6.69
Agriculture	136.81	53.65	124.11	48.67	119.29	46.78
Vacant land	16.72	6.56	14.45	5.67	7.96	3.12
Others	6.54	2.56	7.51	2.95	8.43	3.31
Total	255.00	100.00	255.01	100.00	255.01	100.00

Source: Study Analysis

The decennial trend of land use is shown in Table 2 for three time periods. It is obtained that the existing activity pattern in study area in segment I indicate a development which is constrained due to congestion, excess use of infrastructure facilities and lack of vacant land. Since the area is densely developed, it offers limited scope for further intensification, only densification is possible with increased FSI, depending on the infrastructure availability in the stretch. Whereas in segment II area along the corridor, there is a scope for inducing both accelerating development and densification is possible due to availability of vacant lands.

c) Buffer Analysis

The existing land use characteristics in the year 2006, are analysed with multiple buffers along rail stations. In this case three buffers have been created with a radius of 0.50 km, 1.00 km and 2.50 km taking rail stations as the center. The land use details are tabulated in Table 3 which indicates the less proportion of land use mix in first buffer when compared to other two. The corridor passes through industrial and residential area. Within the City, the area has less vacant land, it offers limited scope for densification, only infill and intensification are possible. In this corridor one side is covered by sea and this also reduces developments along this corridor. Whereas in the Chennai Metropolitan Area and outside the CMA area there is scope for accelerated development and intensification and for inducing densification since this area has more vacant and agricultural lands.

Table 3 : Land Use Statistics Along Rail Corridor in 2006 (Radius 0.5/1.00/2.50 km)

Land Use Category	Area (sq.km.)	Percentage of CMA	Area (sq.km.)	Percentage of CMA	Area (sq.km.)	Percentage of CMA
Radius in Buffer	0.50 km		1.00 km		2.50 km	
Residential	11.97	25.47	26.67	27.78	53.55	21.00
Commercial	2.46	5.23	4.85	5.05	6.51	2.55
Institutional	3.02	6.43	5.63	5.86	8.72	3.42
Industrial	7.56	16.09	12.51	13.03	18.16	7.12
Waste land	1.73	3.68	4.30	4.48	15.33	6.01
Water bodies	3.12	6.64	5.45	5.68	17.06	6.69
Agriculture	12.17	25.89	26.64	27.75	119.29	46.78
Vacant land	2.52	5.36	4.47	4.66	7.96	3.12
Others	2.45	5.21	5.48	5.71	8.43	3.31
	47.00	100.00	96.00	100.00	255.00	100.00

Source: Study Analysis

For this project the area within an influence distance of different buffers has to be calculated station area wise. To calculate this area a buffer has to be created around the railway line for the respective distances. Creation of buffer is a type of proximity analysis in GIS. The buffer actually overlaid on the land use map. Hence, the land use map is given as the first input followed by the buffer and the developments.

The buffer theme is created with multiple buffers around the rail stations. In this case three buffers have been created with a radius of 0.50 km, 1.00 km and 2.50 km taking the rail station as the center. The land use maps are presented in fig.2, fig.3 and fig.4 The land use areas taken as inputs for developing models. The land use maps are given in Figures 5.36, 5.37 and 5.38. It is observed that up to 1.00 km density is high; beyond that it is less. Chennai city is denser than outer city limit. The industries occupy nearby station area within city and outer city is sparsely developed, without adequate infrastructure facilities, discourage the rail user.

Study of the existing pattern of land use of study area clearly shows that developments have mainly occurred along railway stations with mixed land uses due to improper planning. Commercial areas have developed mainly along road leading to railway station and around market. Industrial uses have come up near railway line in segment I. Water bodies, vacant land, Waste land and Agriculture occupies major portion of the land. Existing land use reveals that urban sprawl occur due to the absence of any comprehensive planned development.

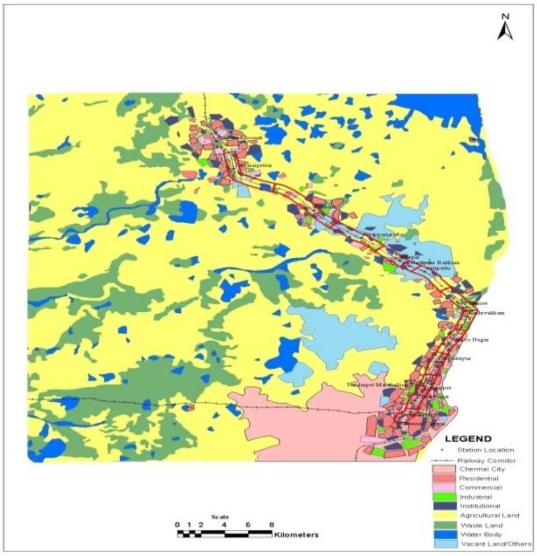

Figure 5 : Station Area Land Use in 2006 (0.5 km Buffe)

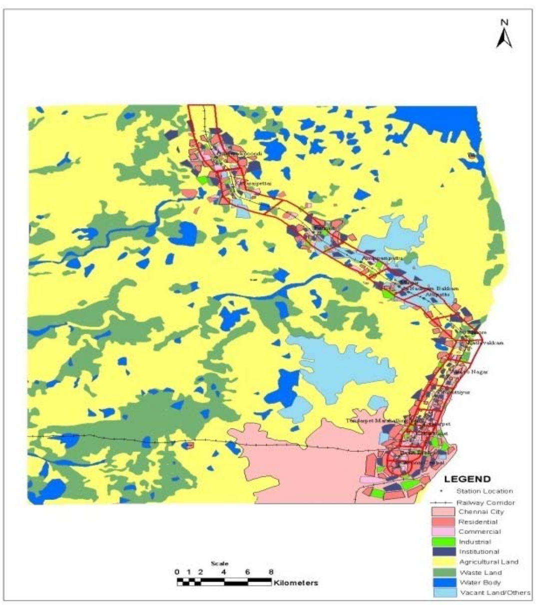

Figure 6 : Station Area Land Use in 2006 (1 km Buffer)

The existing land use pattern along the suburban train corridor is analysed using Geographic Information System. The existing land use in 2001, existing suburban train corridor accommodated 10.62 lakhs population in segment I and 2.90 lakhs population in segment II. The population break-up for each station is collected. It is divided into two parts: segment I (within Chennai City) and segment II (Outer Chennai City). Densification prospects are very high in segment II than segment I.

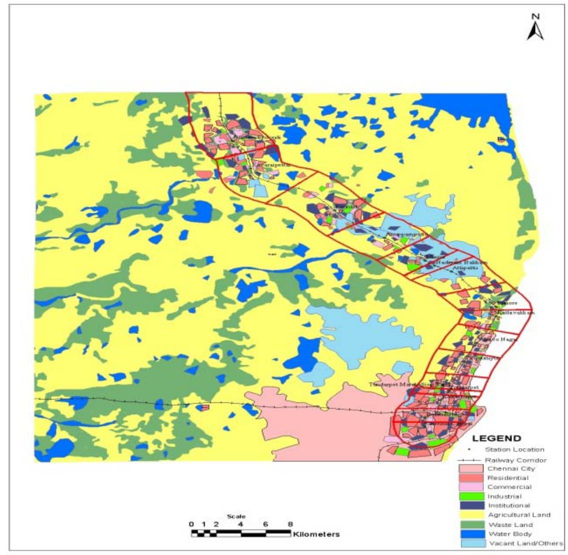

Figure 7 : Station Area Land Use in 2006 (2.5 km Buffer)

IX. System Characteristics and Patronage Evaluation

In 2006, suburban train operates 78 services per day between Chennai Central and Gummidipoondi at a distance of 46.08 km, inter-station distance of 3.29 km. The maximum frequency is 4 trains per hour and off-peak is only 1 train per hour. The transit unit carries a capacity of 2760 passengers per transit unit. Each car rake / Electrical Multiple Unit has a carrying capacity of 306 passengers (including sitting and standing). The minimum headway that can be maintained for the present system is every 15 minutes (Southern Railways 2006).

a) Evaluation of Ridership

One of the main objectives of the study is to estimate the present ridership along the suburban rail system. Hence, a survey on passenger boarding and alighting was carried out on April 2005 during morning and evening peak hours.

The analysis gives the following details:

- Hourly variation of Passenger trips
- Directional Patronage
- Analysis on highly patronized stations

In study corridor, it is observed that maximum passenger trips hourly variation is 3800. Directional patronage clearly indicates that towards Gummidipoondi traffic is heavy during morning hours. The directional split during the morning period is 64:36. Morning passenger trip is 15426 and evening passenger trips is 14560. This justifies that the evening passenger trips are return trips. Peak period is observed between 7:00 AM and 9:00 AM in the morning and the evening peak between 5:00 PM and 7:00 PM. The suburban stations are classified into four major categories based on the number of passengers handled per day which ranges from 2,000 to 10,000 passengers.

b) Train Passenger loading analysis

From the total number of trips handled per day at different stations during the year 2003-04, it has been observed that the number of trips handled at Chennai Central is maximum and Basin Bridge handled at minimum. In this corridor, Industries are clustered around railway stations, Residential and Commercial locations are found close to National Highways not close to railways.

For Chennai Central–Gummidipoondi, station to station passenger loading and section wise passenger loading is analyzed. It is found that 11.85 million commuters have traveled in 2003-04. On an average 0.66 lakhs of commuters travel in a day within the corridor Chennai Central – Gummidipoondi but approximately station wise boarding and alighting passengers per day is 1.08 lakhs. From that, it is found that other corridor passenger using this corridor. Hence it is clear that inter corridor traveling also prevails to certain extent.

X. Analysis and Model Development

The model of the Population, Land Use and Transport interaction using the System Dynamics (SD) approach has been implemented in the 'STELLA' environment ('STELLA 8.1' package). The modeling tool which is an object- oriented simulation environment allows the development of Transport Energy interaction models with significantly less effort than using traditional programming languages. It has a user-friendly graphical interface and supports modular program development. Using this tool, the modeller defines objects representing physical or conceptual system components and indicates the functional relationships among these objects. Building on these strengths, the general architecture of the present work is framed.

a) Phases of Model Building Process

Generally the model building process can be divided into two phases namely the Conceptual phase and the Technical phase. It is the process of defining a problem out of a situation, developing various relationships quantitatively, testing the model with several policy options and analysing the behaviour of the model.

The first phase in the model building process involves recognizing and defining a problem. Important properties of dynamic problems are that they contain quantities that vary over time. System Conceptualization phase involves committing to paper the important influences believed to be operating within the system. Systems may be represented on paper in several fashions and the three most common being causal-loop diagram, plots of variables against time and computer flow diagrams. In model representation Phase, models are represented in the form of computer code that can be fed into the computer, that is in the form of computer programming languages. Under model behavior phase, simulation is carried out in this phase to determine how all the variables within the system behave over a period of time.

In model validation stage numerous tests must be performed on the model to evaluate its quality and validity. These tests range from checking for logical consistency, to matching model output against observed data collected over time for validating the model and to more formal statistical significance of the parameters used within the simulation process. Policy analysis and model use is the final phase, here the model is used to test alternative policies that might be implemented in the system under study. This phase of the model building process is perhaps the most difficult.

b) Building Blocks of Model

The System Dynamics tool used in this study to model population, land use and transport interaction has four basic building blocks as listed below.

- Stock

Stocks or levels are used to represent anything that accumulates. An example of stock would be population level at one time.

- Flows

Flows or rates represent activities that increase and decrease stocks. An example of flow includes birth rate and death rate.

- Connectors

Connectors are used to establish the relationship among variables in the model. The software represents them graphically as arrows. They carry information, which can be a quantity, constants, an algebraic relationship or a graphical relationship.

- Converters

Converters transform input to output. Converters can accept input in the form of algebraic relationships, graphs and Tables. For ease of presentation, the symbols used for flow diagramming of System Dynamics are presented in the Figure 8.

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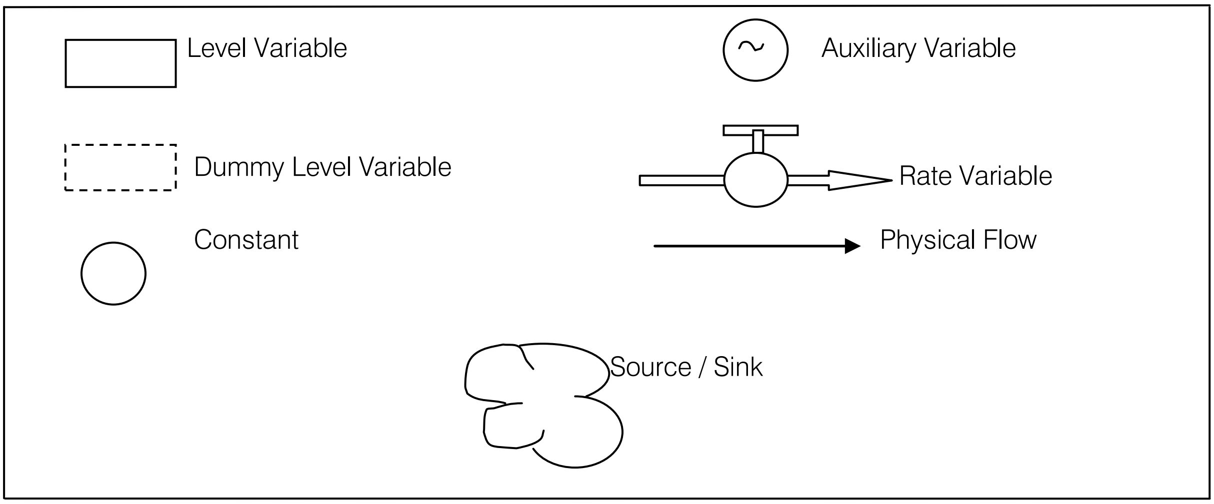

Figure 8 : Flow Diagramming Symbols

c) Population Sector

The system dynamic model is as shown in Figure 2. Population is influenced by the Birth rate, Death rate, In-migration and Out-migration. The Birth Rate (BR) is influenced by the Birth rate normal (BF N), which is expressed as the number of birth per thousand. BR is determined by multiplying population with BF

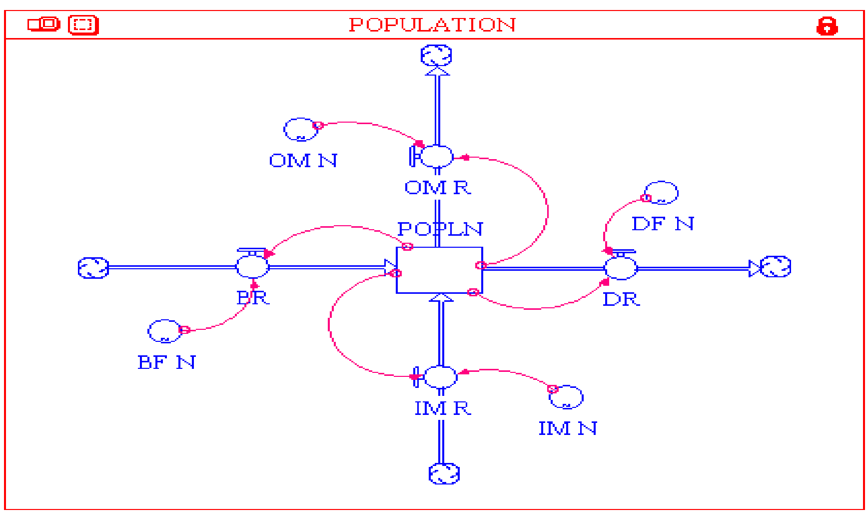

Figure 9 : Population Model

d) Land use Sector

The landuse sector is illustrated in Figure 3; it is used to simulate the changes in the various landuses. From the past and present landuse data collected, the rate of change of land uses have been determined. Landuse conversions from other land area (OTH AR) to rip generating residential land area (GEN AR), from trip generating land area to commercial area (COM AR) was determined and projected. From the GEN AR, FAR and Population projected from the population sector, the Density is calculated. All areas other than GEN AR and OTH AR are considered to be Trip Attracting Areas (ATT AR). The total developed area (TD AR) is sum of ATT AR and GEN AR.

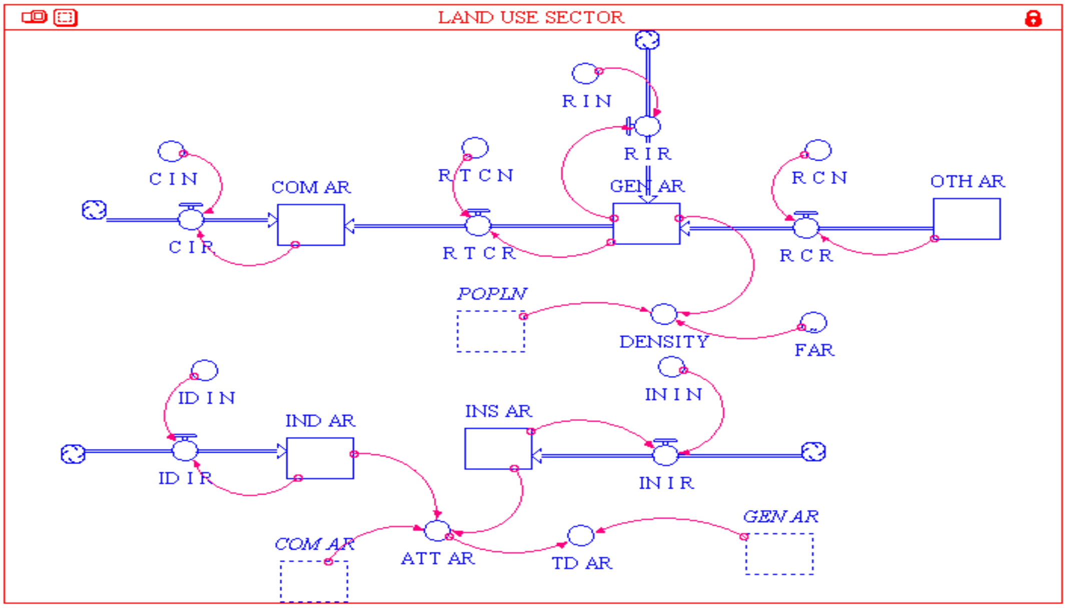

Figure 8 : Land Use Model

e) Transport Sector

In order to evaluate the trip production, transport sector (Figure 4) is considered in the study. The public transport system in the study area comprises of both road and rail facilities. The objective of the land use transport model is to bring sustainable land use development through rail transit ridership. Therefore, the model is tested for various policies to obtain an optimum land use and transport facilities. Switchover of passengers from personal modes (PVT TRP) and bus (TOT BUS TRP) to rail (TOT RAIL TRP) is considered. The public and personal modal trips are calculated from the total trips (TOT TRP) using respective model fractions from (PUB TRP) the public transport trip the bus and rail trips are derived. The simulation values in segment I is given in Table 3.

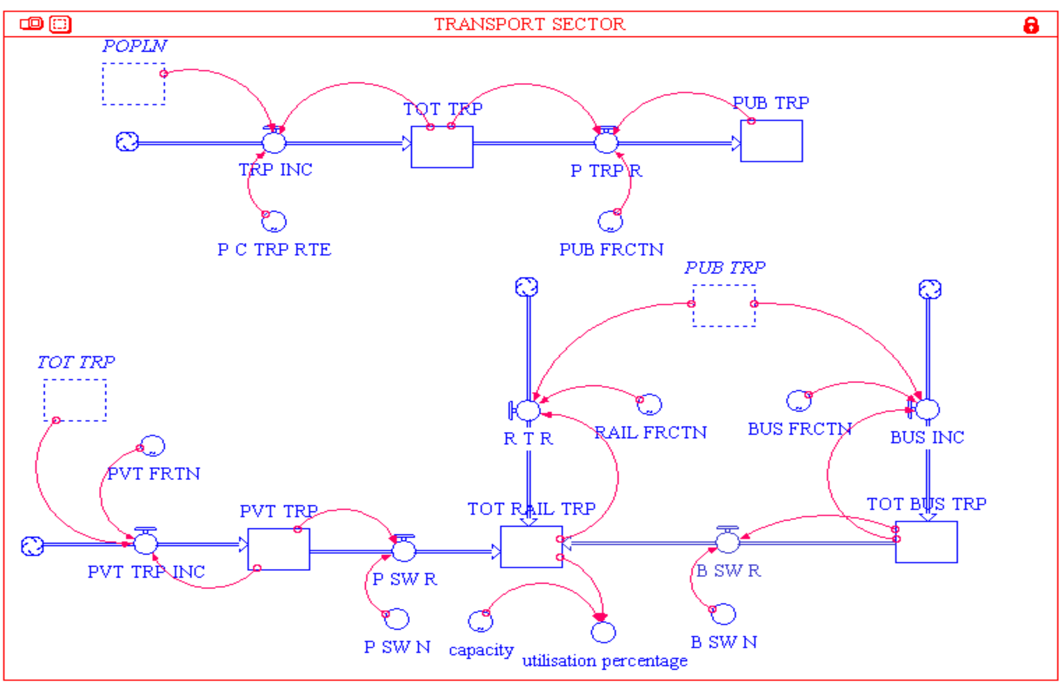

Figure 11 : Transport Model

Table 4 : Results of All the three Simulations in segment I Model (Horizon year 2026)

Simulation	Population	Density (persons/ha.)	Total trips	Rail trips	Bus trips	Public transport trips
Simulation I (Do Minimum)	13,02,305	338	20,69,098	1,98,350	5,83,180	6,69,986
Simulation II (By increasing FSI 1.5- 3.00 and rail operations)	21,73,690	282	35,00,638	5,72,826	12,30,887	18,55,089
Simulation III (By increasing FSI 1.5-4.00, rail operations and addition of new lines)	28,74,338	280	46,04,386	12,06,008	17,20,278	30,65,982

Source: Primary Analysis

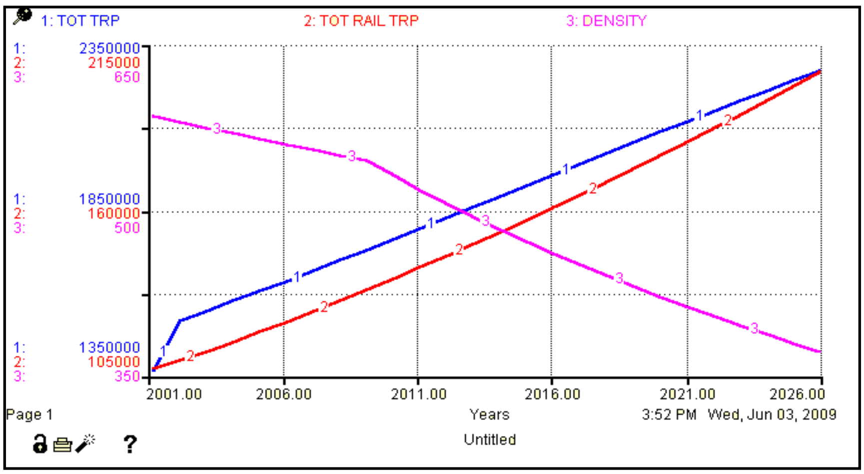

Figure 12 : Sensitivity of Population on Model results

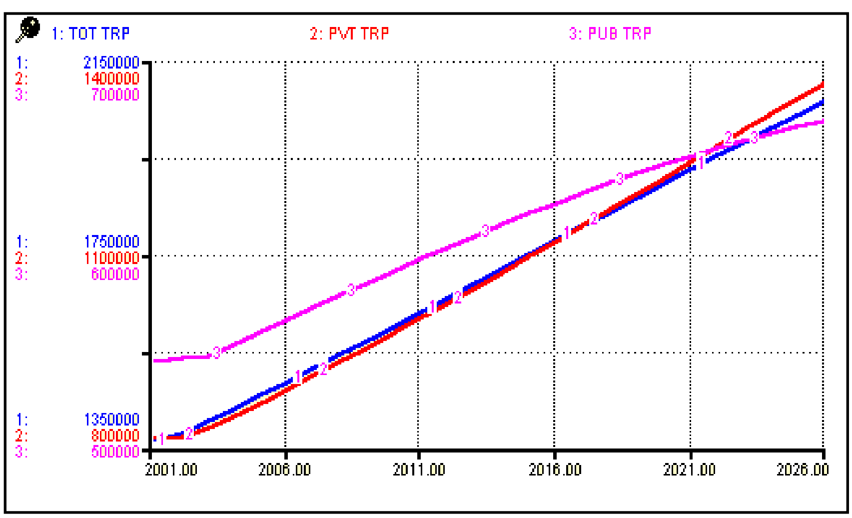

Figure 13 : Results of Transport Model –Simulation I

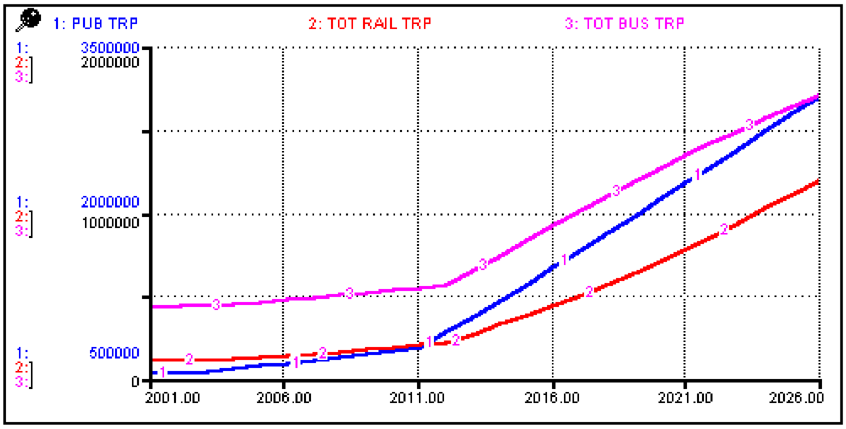

Figure 14 : Results of Transport Model – Simulation III

Hence among the three Simulations the last Simulation namely Simulation III is revealing good share of rail transit trip to achieve sustainable development. When the model is validated for the year 2001, it shows that the model results coincide with the actual values with a maximum deviation of 1.52 percent. Hence the simulated result revealed good approach to the actual, with quite tolerable deviation. Similarly the various simulations are generated in segment II area. The simulation values in segment II is given in Table 4. The results of segment II model are given in Figure 9 to 11.

Table 5 : Results of All the three Simulations for segment II Model (Horizon year 2026)

Simulation	Population	Density (persons/ ha.)	Total trips	Rail trips	Bus trips	Public transport trips
Simulation I (Do Minimum)	11,18,141	107	16,92,165	1,41,735	3,98,676	5,21,391
Simulation II (By increasing FSI 1.5- 3.00 and rail operations)	24,97,246	197	37,45,382	5,17,378	11,59,746	18,50,967
Simulation III (By increasing FSI 1.5-4.00, rail operations and addition of new lines)	35,18,785	208	52,21,294	11,51,717	17,06,253	32,26,697

Source: Primary Analysis

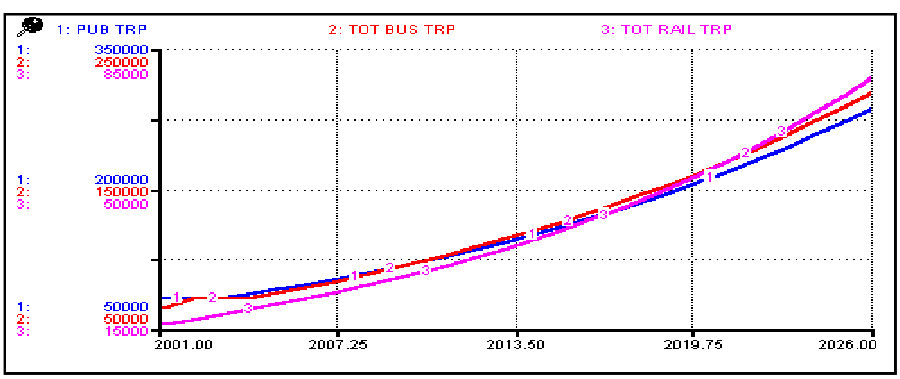

Figure 15 : Results of Transport Model – Simulation I

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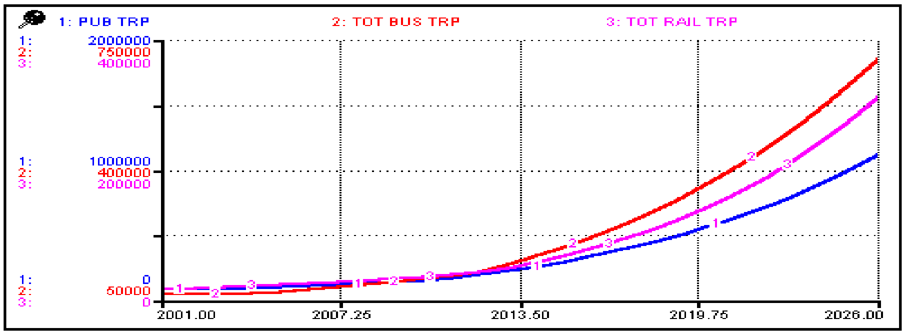

Figure 16 : Results of Transport Model – Simulation II

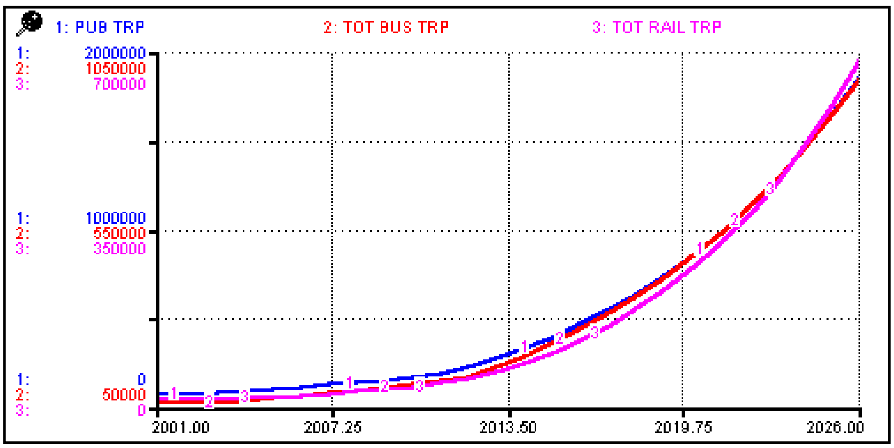

Figure 17 : Results of Transport Model – Simulation III

Hence among the three Simulations the last Simulation namely Simulation III reveals good share of rail transit trip to achieve sustainable development.

XI. Conclusions

The following conclusions are drawn from this study based on the model analysis carried out in Northern suburban rail corridor:

- It is observed that maximum distance to reach nearby station is 1.00 km by walk and 2.50km by personalised and para transit modes.
- The analysis shows that there is an increase in ridership of suburban service due to the shift from bus and personalized modes if the rail transit system capacity is augmented.
- It is observed that by providing increased frequency, reduction in fare, Inter-modal transfer facilities, common ticket system, increasing accessibility and capacity; the number of rail transit users can be increased.
- Present development along the corridor does not increase patronage much because of scattered and unplanned developments which discourage the rail users. Hence, densification / TOD is proposed to attract more passengers along this corridor.
- The present design capacity of the northern suburban railway corridor is 285120 passengers per day. In design capacity, the utilized capacity was only 37 percent in minimum headway of 15 minutes. Hence, the corridor is highly under-utilized.

XII. Results of Segment I

- In segment I for simulation I, the increase of population is only 13,02,305 lakhs along the rail corridor. In simulation II, the increase of population is 21,73,690 lakhs, which is in the order of 1.67 times more than that of simulation I due to partial improvement and in simulation III, the population increase is more than 2.21 times than that of simulation I due to maximum improvement.
- In segment I, under simulation I, the density increases to 338 persons / ha., which is high. In simulation II, the density decreases to 282 persons per ha., and in Simulation III it is 280, which are acceptable.
- The rail transit share in simulation II is 2.89 times more than Simulation I in segment I, this is due to increasing the FSI and augmenting the rail transit operations partially, in the simulation analysis.
- The rail transit share is 6.08 times more in simulation III than Simulation I in segment I, due to not only

increasing the FSI but also augmenting the rail transit operations due to maximum improvement.

XIII. Results of Segment II

- In segment II, simulation I, the increase of population is only 11,18,141 lakhs along the rail corridor. In simulation II, the increase of population is 24,97,246 lakhs, which is in the order of 2.23 times more than that of simulation I due to partial improvement and . In simulation III, the population increase is more than 3.15 times than that if simulation I due to maximum improvement.
- The rail transit share in simulation II is 3.65 times more than Simulation I in segment II, due to not only increasing the FSI but also augmenting the rail transit operations partially.
- The rail transit share in simulation III is 8.12 times more than Simulation I in segment II, this is by increasing the FSI and augmenting the rail transit operations due to maximum improvement.
- In the simulation III, it is seen that by increasing the FSI, modal share, addition of new lines and switchover rate, the maximum capacity of suburban rail corridor could be utilized.
- Hence, the possibility of land use development in segment I needs densification and segment II area requires accelerated development and densification to enhance the patronage of the present suburban system with increase frequency and capacity, also addition of new rail line.

XIV. Recommendations

- Population increase always increases the growth of public transport and personalized vehicles, but the present road system is beyond endurance. It emphasis the need for TOD along the corridor.
- TOD would enhance the Public Transport users and consequently discourage the personalised vehicle users for ensuring sustainable environment.
- Planned and orderly TOD development would also promote sustainable transport development.
- Allowing higher FSI from 1.50 to 4.00 along the study corridor would justify TOD.
- Providing incentives for developers to promote land use in the proposed stretch, or some sort of policy decisions are needed from Government side to attract the settlement of the people.

Since, rail transit has a number of advantages of its own namely, decrease in environmental pollution, saving travel time, minimized energy consumption, cost effective, it should be encouraged to its maximum extent to ensure standard of living and achieve sustainable transport developments in the long run.

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Evaluation of the Parameters of SOM Model for Selecting Design Section

By Eun-Sang Im & Dae-Hyeon Kim
K-water Institute, Korea

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GJRE-E Classification : *FOR Code: 090599, 090506*

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I. Introduction

Due to the scarcity of industry land resulting from recent development of national industry and from securing new construction sites, a large size of industrial sites are being constructed in many places along the shore of the Korean peninsula. As the area of such construction sites is usually so huge, the ground condition is not homogeneous and the depth of the soft ground that needs to be improved varies in different areas of the site.

Therefore, it is uncommon to apply the same soil properties to all the area of the site, but it is common to do design for several divided sections of the site that have similar soil profile and soil properties. In practice, a commonly used selection method for design zone is that we divide design zones depending on the parameters such as compression index and depth of soft ground, or depending on the purpose of use of the site. These selection methods of design zone cannot differentiate the design zone without considering all the parameters, but they take into account one individual factor, leading to a designer's subjective selection of the design zone. Such an inaccurate determination of design parameters may result in uncertainties in the estimation of settlement of soft ground.

The purpose of the study is to improve the selection of the design zone considering many factors. To accomplish the goal of the study, we employed a SOM (Self-Organizing Map) model, one of the neural network models to Songsang Green City Project. Since so many data and calculations are involved in representing engineering properties and site conditions, we applied the developed selection technique of the design zone to four groups of representative parameters.

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II. Som Model

SOM allows mapping from multi-dimensional data to two dimensional data. SOM is one of the neural network models and is used for grouping. In particular, it is very applicable to the grouping of the multi-dimensional data. Also, it can visualize the data, predetermine the structure of the grouping result, and acquire good results very quickly although there are so many data.

Kohonen (1982) of Helsinki University introduced a self structuring system. This system allows to map the input data that exist in the external space to the internal space that the system defines, without user's assistance. Kohonen called this system Self-Organizing Feature Map or (adaptive vector quantizer AVQ), and many kinds of SOM have been proposed and developed.

SOM has a similar algorithm to VQ (Vector Quantum) such as K-Means technique and is a kind of unsupervised learning algorithm. It maps independently n-dimensional data to two dimensional data and the typical structure of SOM is shown in Figure 1.

The structure of SOM has n number of input nodes when it uses n-dimensional input data. When input data are categorized as k number of regions, it has k number of output nodes. All the input nodes are connected to all the output nodes and they have their own weight. Generally input nodes transmit input data to the network, and output nodes calculate the distance using the input data and weight.

Figure 1. Typical structure of SOM

The philosophy of Kohonen's network is that only winner can output- that is, the principle of "winner take all", and that their neighbors only control their weight. To do this, the weight vector of node has certain values and should be appropriately initialized. Also, each node controls the weight in the course of three steps such as competition process, close radius (근접반경) process, adaptation learning process.

a) Competitive Process

Each neuron competes to have privilege for possessing to learn and in this process, a neuron wins that has the nearest distance between the weight vector and the input vector. The input pattern with m number of input and the weight vector can be defined as follows.

$$X = [x_1, x_2, \cdots, x_m]^T \qquad (1)$$

$$W_j = [\omega_{j1}, \omega_{j2}, \cdots, \omega_{jm}]^T, \quad j = 1, 2, \cdots, l \qquad (2)$$

Where l= the number of neuron

The winner neuron ($i(X)$) out of output neuron is determined by the following condition.

$$i(X) = \mathrm{arg}\min \| X - W_j \|, \quad j = 1, 2, \cdots, l \qquad (3)$$

Thus, the selection of the winner neuron is to select the weight vector that is most similar pattern. Euclidean Distance is used to measure similarity matching.

b) Close Radius' Adjustment Process

Kohonen's system uses lateral inhibition through cooperative process with neighboring neuron, which can be similarly observed from the biological model. Learning about the input vector is allowed to both the winner and the neighboring neuron in the competition process. The radius for determining the neighboring neuron becomes small, and a very few neuron have chances to learn. Finally, the winner controls the weight.

In addition, Gaussian function is used in the process of controlling the geometric radius, as it has symmetric and converged characteristics. The function (h_{bi}) that defines its neighboring radius and the function (d_{ji}) that represents the distance between neighboring neurons are as follows.

$$h_{bi}(t) = \exp\left(-\frac{d_{ji}^2}{2\sigma^2(t)}\right), \quad t = 0, 1, 2, \cdots \qquad (4)$$

Where d_{ji} can be defined in such a way that the distance vector r_j is expressed with an expected j neuron and a winner neuron j.

In general, an exponential damping σ can be expressed as follows.

$$\sigma(t) = \sigma_0 \exp\left(-\frac{t}{\tau_1}\right), \quad t = 0, 1, 2, \cdots \qquad (6)$$

In equation 6, σ_0 is the value of σ in the initialization of SOM algorithm, τ_1 is the time constant.

c) Process of Adaptation Learning

When the process aforementioned is completed, the adjustment of the weight such as synapse is finally done. In defining the adjusted weight vector $W_j(n+1)$ in terms of discrete time t from the unadjusted weight vector $W_j(n)$, the rule for the adjustment can be expressed using the following equation.

$$W_j(n+1) = W_j(n) + \alpha(n) \cdot h_{bi}(n) \cdot [X - W_j(n)] \qquad (7)$$

Where, α is the decreasing learning rate with increasing t and α can be expressed such that it satisfies the initial value α_0 and exponential reduction.

$$\alpha(t) = \alpha_0 \exp\left(-\frac{t}{\tau_2}\right), \quad t = 0, 1, 2, \cdots \qquad (8)$$

τ_2 is the another constant of SOM algorithm, as in equation 6, Figure 2 shows the renewal process of weight vector.

Figure 2. Renewal process of weight

The adjustment of the weight of adaptive learning in equation 7 undergoes Self-Organizing Phase and Convergence Phase. The Self-Organizing Phase is the phase that h_{bi}, defined as the adjacent radius, initiates the step including the output layer's every neuron and narrows down the radius around the winner neuron. The Convergence Phase is the fine tuning phase that very small learning rate is selected, the nearest neuron is included, and the winner neuron is ultimately selected.

III. Implementation of Som Model

a) The Site Area

The site in this study is located Songs an in Korea. It is adjacent to Lake Siwha to the north, Island Daebu and Island Yeugheung to the west, Siwha and Banwoel Industrial complexes around the site, and the West Coast Highway to the east. This site has been made from a large size reclamation project where a seawall has been constructed to prevent seawater. Due to desalination of Lake Siwha, alluvial layer is mainly found. The site consists of a sedimentary layer and a thick alluvial layer (soft soil).

Figure 3.The site area

In order to identify the applicability of SOM model, District 1 from Songs an Green City has been selected. Soil parameters used in the study are obtained from insitu field tests and laboratory tests. For reference, the site, in the master plan, was subdivided into 7 zones based on the distribution of soft soil, which was done in the designer's own judgment.

Figure 4. The site area Locations of boring and physical and mechanical properties of soil

Figure 5. Design zone considering soft soil

b) Discussion of Results of SOM Model

In this study, we used the SOM toolbox developed in University of Helsinki and Matlab to verify SOM model and its applicability. Figure 6 exhibits the flowchart of SOM and its first step is to select parameters. For the model to have a good discernment, the number of parameters being used is very important. It is not necessarily good to use many parameters and it is desirable to remove useless parameters or highly correlated parameters for avoiding, so called, the curse of dimension. As many parameters require huge data and calculation, parameters should be appropriately reduced

Figure 6. Flowchart of SOM model

In this study, we take into consideration 12 physical and mechanical properties from 41 locations: water content (Wn), specific gravity (Gs), liquid limet (LL), plastic Index (PI), percent passing #200 sieve (2μm), Unified Soil Classification System (U.S.C.S), unconfined compressive shear strength (Q_u), triaxial shear strength (C_{uu}), sensitivity(S_t), preconsolidation (P_c), modified compression index (C_{CF}), void ratio (e_O). Out of these 12 parameters, the 1st parameter group considers 5 parameters that are not affected by the ground condition, the 2nd parameter group does 3 parameters related to the initial state and mechanical properties, the 3rd parameter group does physical and mechanical properties, and the 4th parameter group does all of the above. The applicability of SOM has been studied for these 4 types of parameter group.

Table 1. Physical and consolidation properties of soils

In SOM training, as the size of map and array affects significantly the performance of SOM, commonly used hexagon array $5\sqrt{N}$ (n = number of training input data) map size has been used. This classification is done considering additional geological characteristics as it is for the design zone of the site.

(1) The 1st parameter group

Figure 7 presents training results of 6×6 SOM model for the 1st parameter group considering physical properties. Figure 7(a) shows the distribution of unified distance matrix (U-matrix) on SOM that unifies each parameter, and Figure 7(b) and 7(c) represent the optimum number of cluster and results of classification, respectively.

Figure 7. Training results of 6×6 SOM model for the 1st parameter group

The results of classification except for the clusters with small number of clusters are shown in Figure 8. In the case of separating the design zones, the constructability can be secured when designing with zones considering the location of the data. The design zones are divided into two zones considering geological conditions

Figure 8. Results of design zone of 6×6 SOM for the 1st parameter group

(2) The 2nd parameter group

For the 2nd parameter that considers the initial state and mechanical properties, 10×8 size SOM has been applied. However, it is hard to select design zones because 4 clusters are complicated.

Figure 9. Results of design zone for the 2nd parameter group

(3) The 3rd parameter group

The 3rd parameter group is the parameter group that considers physical and mechanical properties. A pattern categorization has been performed by applying SOM map with 7×8. As shown in Figure 10, it is optimum to classify two clusters. Based on the result of the categorization, two design zones, shown in Figure 11, have been categorized.

Figure 10. Results of training of 7×8 SOM model for the 3rd parameter group

Figure 11. Results of categorization of design zone for the the 3rd parameter group

(4) The 4th parameter group

The 4th parameter group considersinitial state, the second parameter group, and soil's properties under USCS. Figure 12 shows the result of SOM map with 10×10. Also, based on the result of the categorization, three design zones, shown in Figure 12, have been categorized.

Figure 12. Results of training of 10×10 SOM model for the 4th parameter group

Figure 13. Results of categorization of design zone for the4th parameter group

c) Evaluation of Applicability for Design Zone

In order to find applicability of selection of design zone, the mean value and standard deviation for modified compression index (C_{CF}), one of the most important parameters, have been calculated. Figure 14 shows the distribution of modified compression index for all the site, and its mean value and standard deviation were 0.350 and 0.107, respectively. The statistics for the zone according to the distribution of soft ground is presented in Table 2. As shown in Table 2, the mean value and standard deviation are in the range of 0.289 ~ 0.429, and 0.055 ~ 0.169, respectively. Note that for some zones, the number of data is too small, the reliability of the mean value is questionable. As Zone 1, 2, 4 and 6 have small data and relatively high standard deviation, it seems unreliable to do consolidation analysis with the mean values of these zones.

Figure 14. mean value and standard deviation for modified compression index (C_{CF})for all the site

Table 2. mean value and standard deviation for existing design zone

(1) The 1st parameter group

In order to find applicability of SOM model, the mean value and standard deviation for the modified compression index of the main cluster in each design zone been calculated. Based on the results, design zone 1 tends to have high standard deviation, but in general categorization of the design zone has been done reasonably.

Figure 15. mean value and standard deviation for modified compression index (C_{CF}) for each design zone

(2) The 3rd parameter group

The mean value and standard deviation for the modified compression index have been calculated. The results have been found to be improved.

Figure 16. mean value and standard deviation for modified compression index (C_{CF}) for each design zone

(3) The 4th parameter group

In order to find applicability of the 4th parameter group SOM model, the mean value and standard deviation for the modified compression index of the main cluster in each design zone has been also calculated. It is found that design zones 1-3 have small standard deviation.

Figure 17. mean value and standard deviation for modified compression index (C_{CF}) for each design zone

Based on the results, the 4th parameter group was found to be the most appropriate model because modified compression index has been used as categorization factor. However, it is more desirable to select the 4th parameter group considering the initial state, physical and mechanical properties.

Table 3. mean value and standard deviation for each parameter group

IV. Conclusion

In this study, we attempted to develop a more reasonable method of estimating consolidation settlement using SOM for Songsang Green City Project in Korea. On the basis of the information obtained from the site investigation, categorization using SOM has been made. The following conclusions can be drawn based on the results of the study.

- We were able to improve the design zone by using SOM technique. In dividing the design zone for a wide area of the site, many parameters have been considered unlike the existing method considering one parameter.
- When using SOM technique for the categorization of design zone, it is desirable to utilize initial state, physical and mechanical properties of soft ground.
- For modified compression index, compared with other parameter groups such as the 1st parameter group considering only physical properties, the 2nd parameter group considering initial state and mechanical properties, the 3rd parameter group considering mechanical and physical properties, the 4th parameter group considering initial state, physical and mechanical properties obtained more reliable results with less standard deviation.
- It is better to use the 3rd parameter group as we need to take into account physical and mechanical properties of soils as well as initial states.

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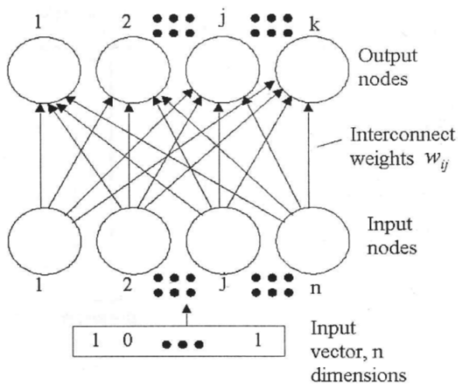


Figure 1 : Typical structure of SOM

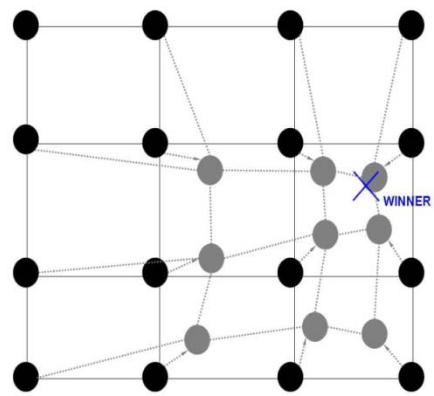


Figure 2 : Renewal process of weight

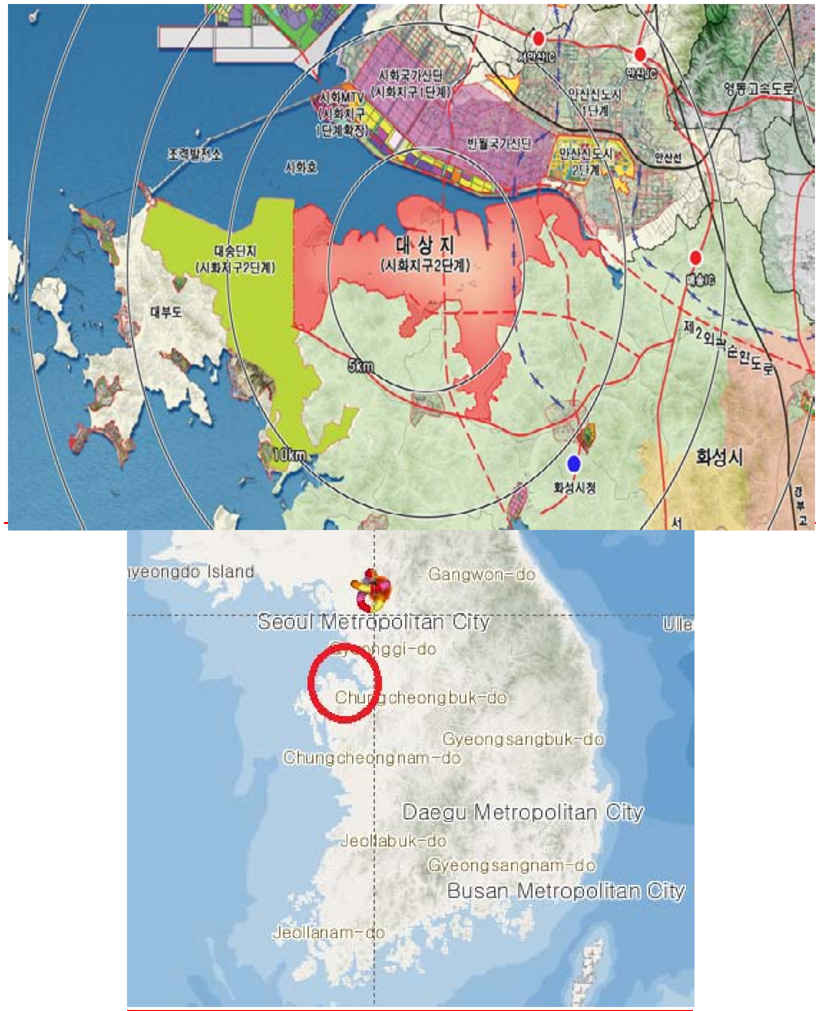


Figure 3 : The site area

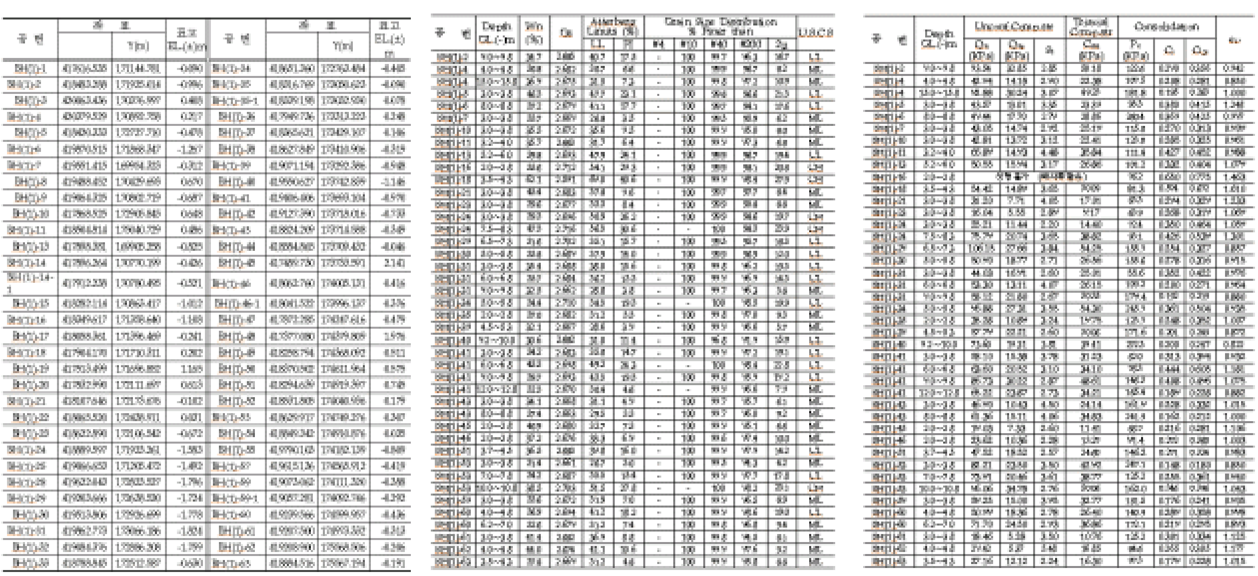


Figure 4 : The site area Locations of boring and physical and mechanical properties of soil

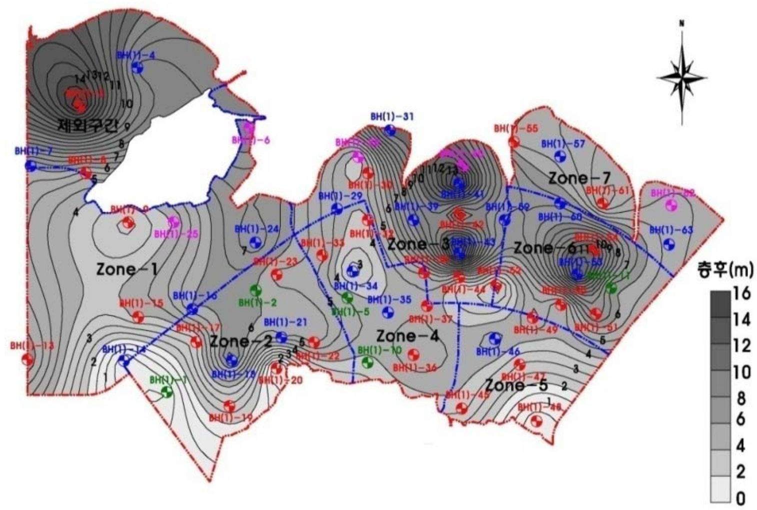


Figure 5 : Design zone considering soft soil

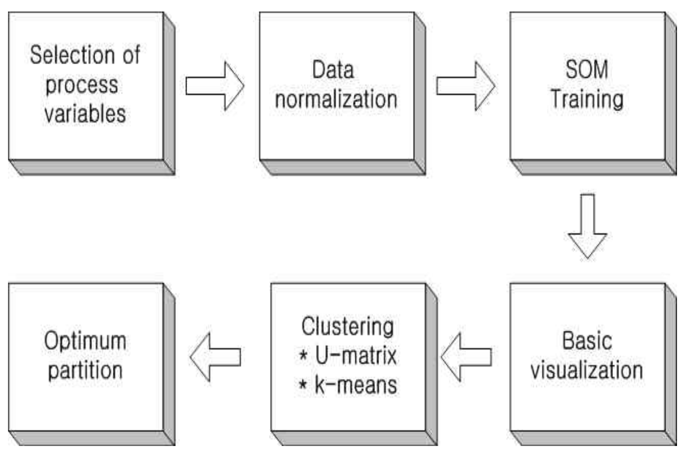


Figure 6 : Flowchart of SOM model

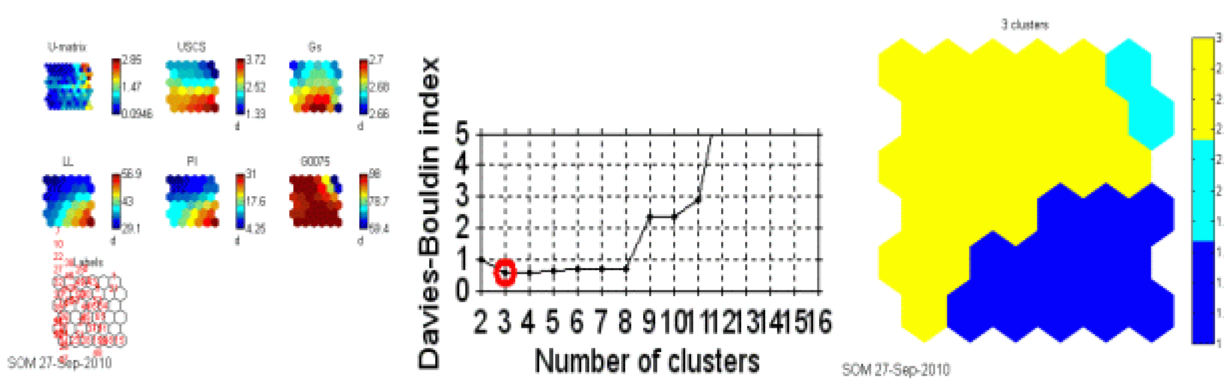


Figure 7(a) Figure 7(b) Figure 7(c)

Figure 7 : Training results of 6×6 SOM model for the 1st parameter group

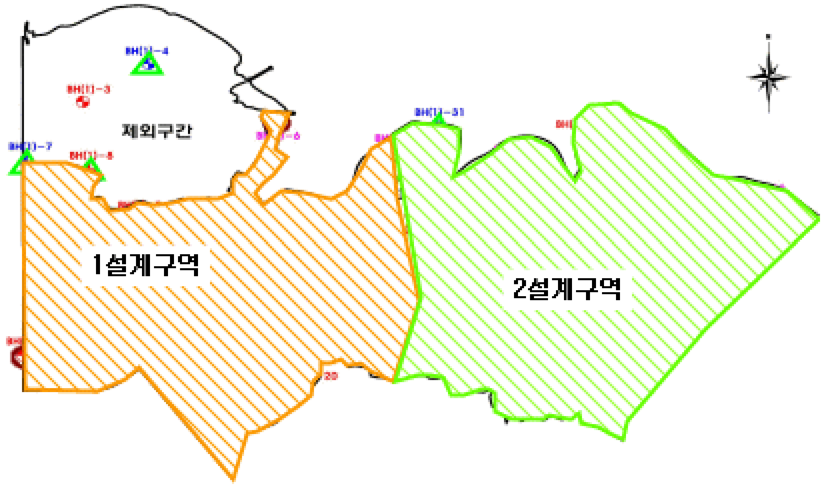


Figure 8 : Results of design zone of 6×6 SOM for the 1st parameter group

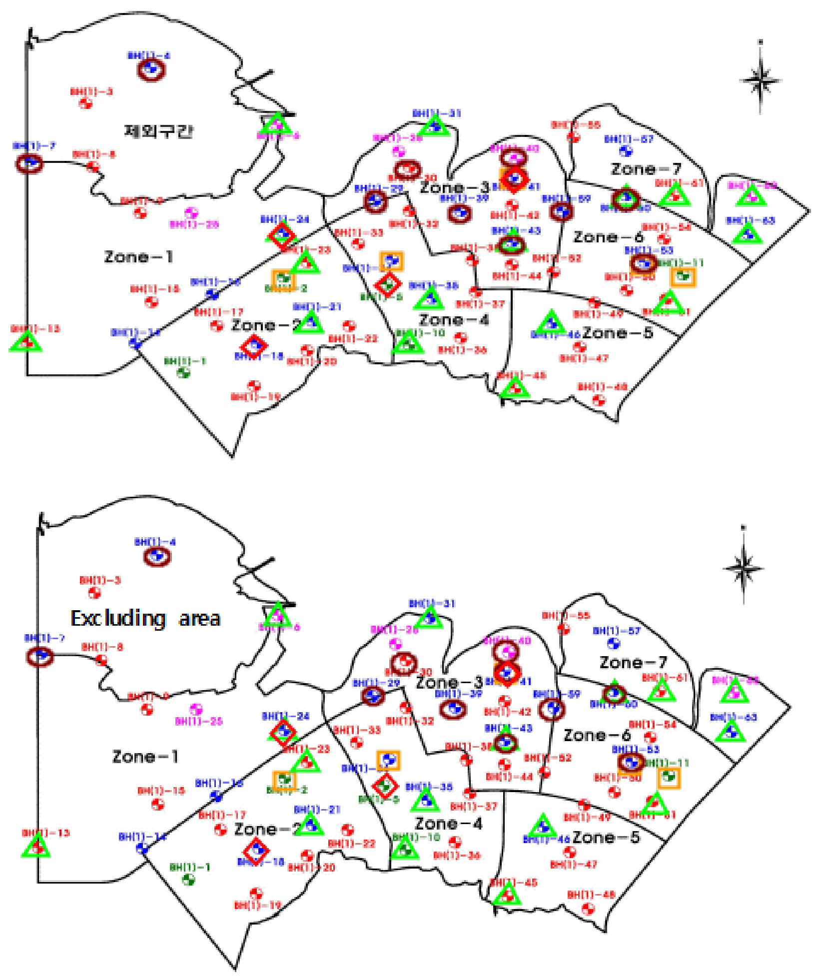


Figure 9 : Results of design zone for the 2nd parameter group

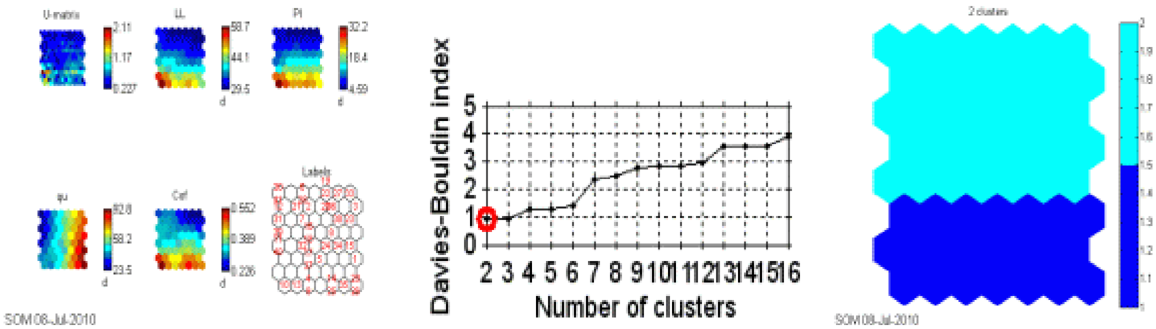


Figure 10 : Results of training of 7×8 SOM model for the 3rd parameter group

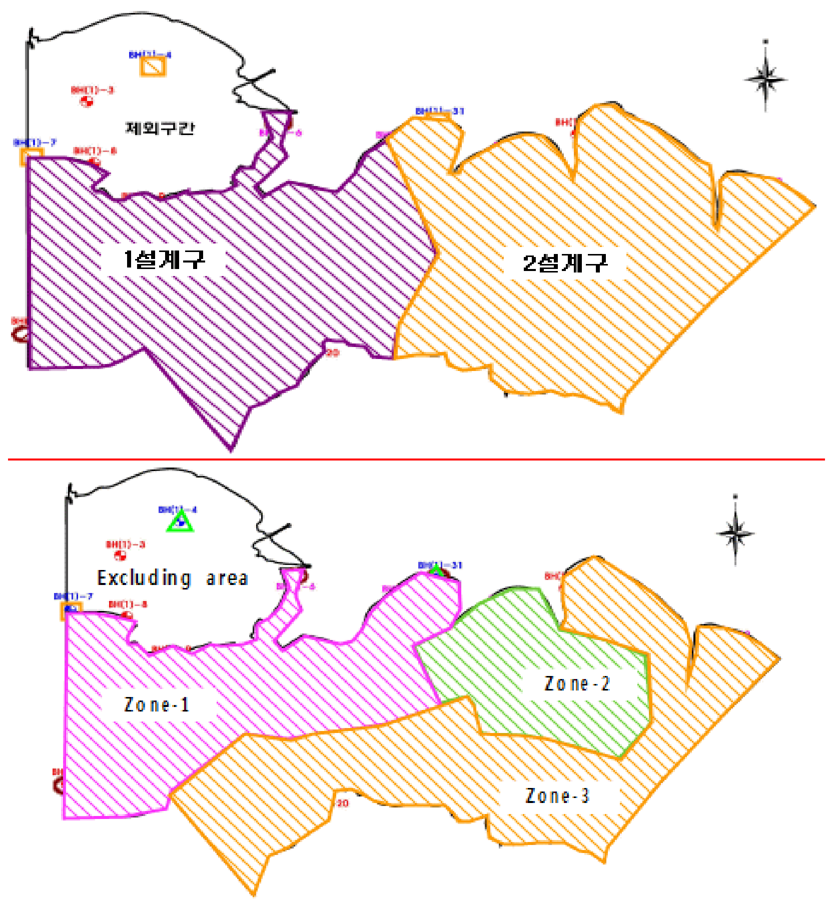


Figure 11 : Results of categorization of design zone for the the 3rd parameter group

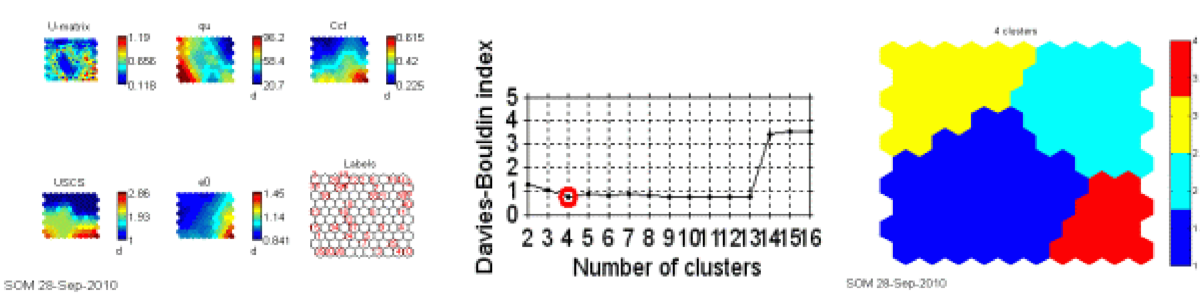


Figure 12 : Results of training of 10×10 SOM model for the 4th parameter group

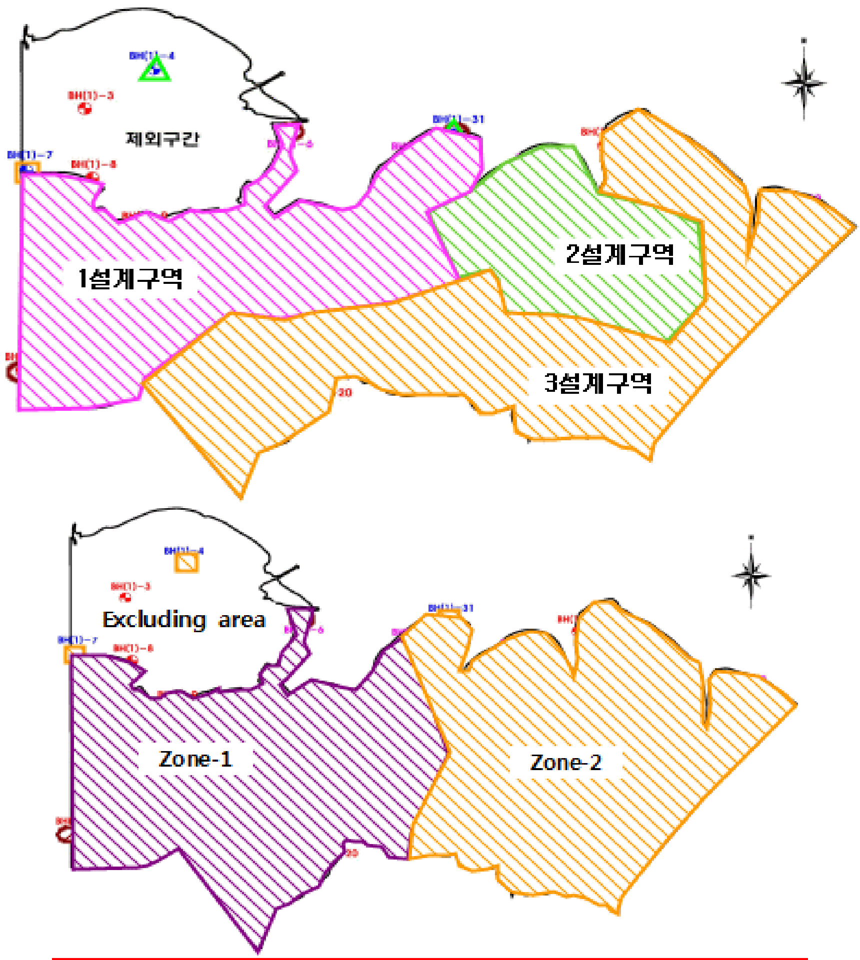


Figure 13 : Results of categorization of design zone for the 4th parameter group

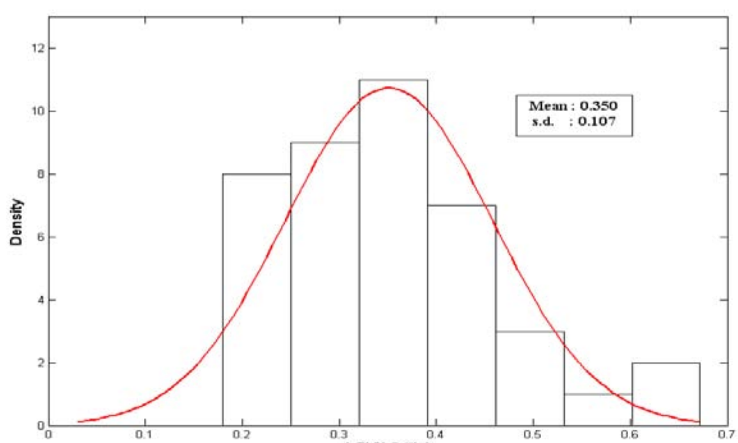
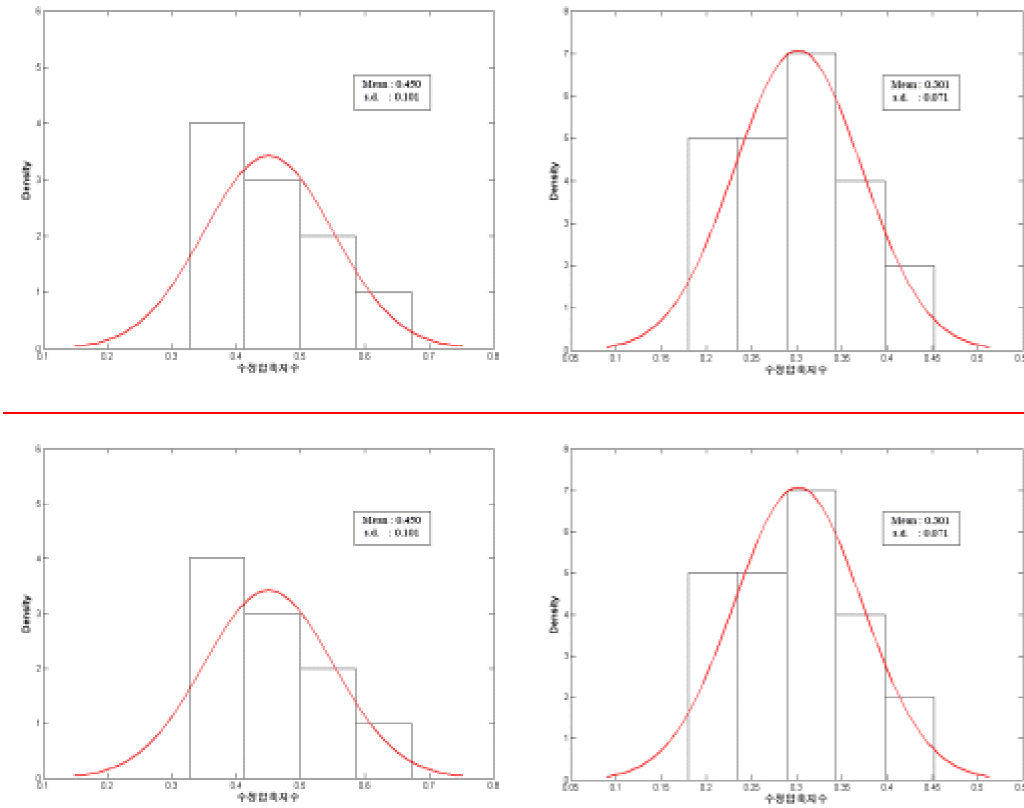
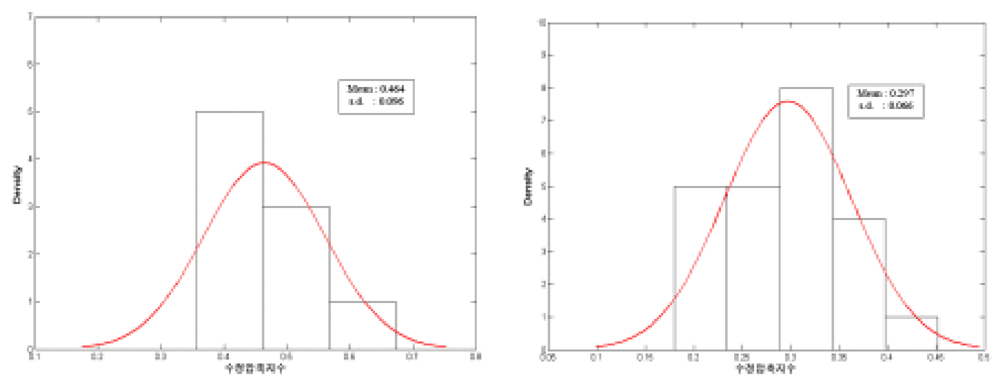


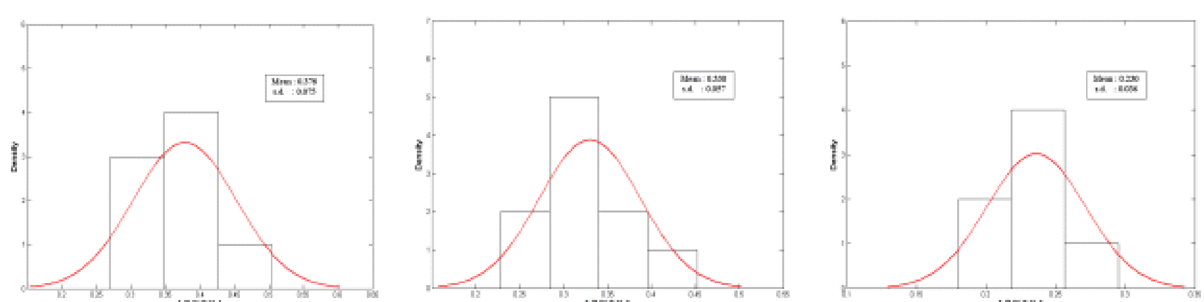
Figure 14 : Mean value and standard deviation for modified compression index (CCF) for all the site



a. 1st parameter group



b. 3rd parameter group



c. 4th parameter group

Figure 15 : Mean value and standard deviation for modified compression index (C_{CF}) for each design zone

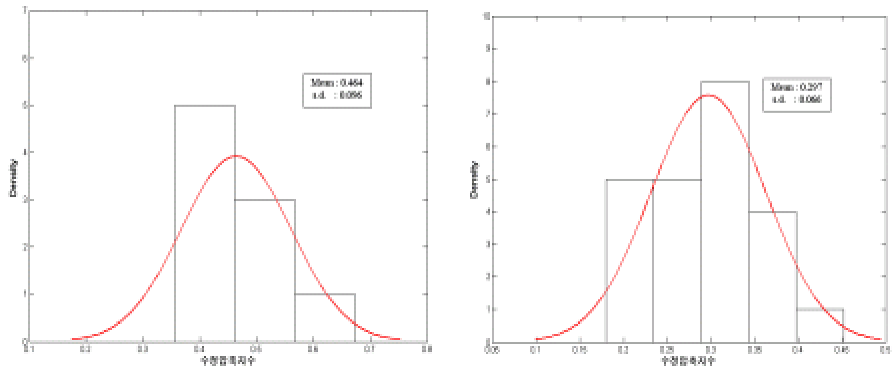


Figure 16 : Mean value and standard deviation for modified compression index (C_{CF}) for each design zone

Table 1 : Physical and consolidation properties of soils

	Parameters used	comments
1st parameter group	Specific gravity(Gs), Liquid Limit(LL), Plastic Index(PI), % passing No. 200(2μ), Soil Classification(U.S.C.S)	Considering Physical properties
2nd parameter group	Unconfined compressive strength(Qu), Modified Compressive Index(CCF), Void Ratio(eO)	Considering initial states and mechanical properties
3rd parameter group	Unconfined compressive strength(Qu), Modified Compressive Index(CCF), Liquid Limit(LL), Plastic Index(PI)	Considering physical and mechanical properties
4th parameter group	Unconfined compressive strength(Qu), Modified Compressive Index(CCF), Void Ratio(eO), Soil Classification(U.S.C.S)	Considering initial states, physical and mechanical properties

Table 2 : Mean value and standard deviation for existing design zone

	total	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
Mean	0.350	0.429	0.419	0.326	0.399	0.321	0.338	0.289
Standard Deviation	0.107	0.083	0.167	0.117	0.080	0.056	0.086	0.055

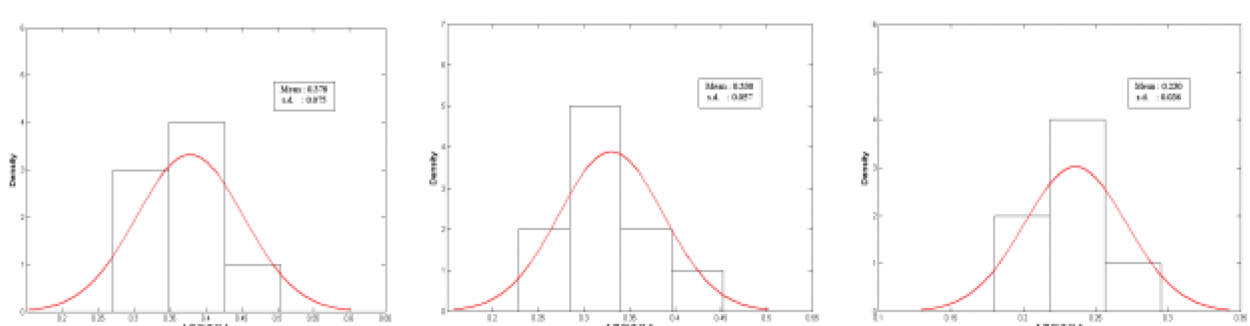


Figure 17 : Mean value and standard deviation for modified compression index (C_{CF}) for each design zone

Table 3 : Mean value and standard deviation for each parameter group

	No. of design zone	Mean value each design zone			Standard deviation for each design zone			comments
1st parameter group	2	0.450	0.301		0.101	0.071		Considering Physical properties
2nd parameter group	-	-			-			Considering initial states and mechanical properties
3rd parameter group	2	0.464	0.297		0.096	0.066		Considering physical and mechanical properties
4th parameter group	3	0.378	0.330	0.230	0.075	0.057	0.036	Considering initial states, physical and mechanical properties

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Analysis of Headway of Heterogeneous Traffic on Indian Urban Roads

By Mr. V Suresh, Dr. R Sivanandan. & Dr. G Umadevi
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Abstract- Headway or inter-arrival time of vehicles is an important parameter in traffic flow, especially in urban roads, since this is one of the main parameters to determine the minimum (safe) gap between vehicles and the capacity. The studies done on headway analysis have mostly concentrated on homogeneous traffic where the flow follows lane discipline. This ideal situation does not exist on Indian urban roads, where the traffic is very heterogeneous, and do not follow lane discipline. A study of headway at different but similar locations of urban four lane divided (two lanes for each direction of flow) roads of a metropolitan city in India (Chennai) was made. The peak hour flow at these locations were observed to be high (varying from 3189 to 9987 vehicles). The study of headway, after removing the 5 % of long headways, at these location indicate that Log normal 2, Inverse Gauss and the Exponential distributions are the most appropriate ones for these conditions of flow. An attempt was made to study the individual inter arrival time of each category of vehicles in the traffic stream. Extensive data extraction was done and the analysis of headway of categorized traffic was made. Appropriate distribution for each category is recommended. The study will be a good input for modeling vehicle generation in simulation studies.

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Analysis of Headway of Heterogeneous Traffic on Indian Urban Roads

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Abstract- Headway or inter-arrival time of vehicles is an important parameter in traffic flow, especially in urban roads, since this is one of the main parameters to determine the minimum (safe) gap between vehicles and the capacity. The studies done on headway analysis have mostly concentrated on homogeneous traffic where the flow follows lane discipline. This ideal situation does not exist on Indian urban roads, where the traffic is very heterogeneous, and do not follow lane discipline. A study of headway at different but similar locations of urban four lane divided (two lanes for each direction of flow) roads of a metropolitan city in India (Chennai) was made. The peak hour flow at these locations were observed to be high (varying from 3189 to 9987 vehicles). The study of headway, after removing the 5 % of long headways, at these location indicate that Log normal 2, Inverse Gauss and the Exponential distributions are the most appropriate ones for these conditions of flow. An attempt was made to study the individual inter arrival time of each category of vehicles in the traffic stream. Extensive data extraction was done and the analysis of headway of categorized traffic was made. Appropriate distribution for each category is recommended. The study will be a good input for modeling vehicle generation in simulation studies.

I. Introduction

Headway or Inter arrival time is a measure of the temporal space between two vehicles. Specifically, the headway is the time that elapses between the arrival of the leading vehicle and the following vehicle at the designated test point. You can measure the headway between two vehicles by starting a chronograph when the front bumper of the first vehicle crosses the selected point, and subsequently recording the time that the second vehicle's front bumper crosses over the designated point. Headway is usually reported in units of seconds.

The distribution of these headways has long been a subject of study. Even though several attempts have been made to find the distribution of headways under homogeneous traffic following lane discipline, the studies under mixed traffic conditions are very few. The distribution tried for flow under homogeneous conditions include negative exponential, shifted exponential, gamma, erlang, log-normal etc for varying traffic volume.

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For traffic prevailing under mixed conditions, where the full width of the road is used by all category of vehicles, from cycle/carts to heavy trucks/trailers, with almost equal priority, there has not been any detailed study done so far. Some attempts made for mixed conditions report that the exponential, erlang, normal and log-normal distributions for various volume levels are appropriate.

II. Literature Review

Isaac and Veeraraghavan (1) have attempted to study the headway distribution under mixed traffic flow conditions. Various distribution models like Negative exponential. Shifted negative exponential, Erlang, Log-normal, Double exponential (Schul's model) and Tripple exponential models were tried and they have reported that no definite conclusion can be arrived regarding the suitability of the models for different volume levels and the percentage composition of vehicle types. It is also reported that the variation in width of the road do not have influence on the distribution. The study has also suggested that the exponential distribution (for flow less than 500 vph), Shifted exponential distribution (for 500 – 2000 vph) and Erlang or composite distribution (for 2000 to 3000 vph) may be adopted for a mixed traffic flow (for a composition of about 20% of 4-wheerlers. 30% autos and 5 % two wheelers):

A study by Chang and Kim (2) has analysed the quantitative methods to define capacity by evaluating the headway and volume distribution from observed traffic flow. Statistical distributions of observed traffic flow were used to remove long headways and reduced cumulative distribution of volumes were only. The authors have said that the rational alternative is to take the 95 % cumulative distribution of observed traffic flow, eliminating 5 % of long headways.

Reddy and Issac (3) have attempted to calculate the practical capacity values of some selected sections on urban roads based on headway analysis. The practical capacity has been calculated based on weighted mean, median, mode and lower mean headway of different classes of vehicles at different volume levels. It was observed that negative exponential distribution is found to be fitting well for vehicle volume less that 720 vph, whereas Erlang distribution fits well at higher volume level of 1440 to 2880 vph.

Hoogendroorn and Bovy (4) have extended the generalised queueing model (GQM) to headway

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observations, segregated according to vehicle type. The estimation method developed is based on the minimization of an integrated squared error distance in the frequency domain. In this study, a new approach for modeling mixed- vehicle- type headway distributions is presented. The model is a straightforward modification of the GQM and distinguishes among different vehicle types (eg. Passenger cars articulated trucks, unarticulated trucks, recreational vehicles, motorbikes). It was expected that because of differences in driving behaviour among vehicle types, bike-type specific headway distributions will exhibit different parameter values.

Arasan and Koshy (5) have reported that the negative exponential distribution is adequate to model headways. It was observed that even during medium and heavy flow conditions, the flow is unconstrained for a considerable proportion of smaller vehicles (two wheelers) and thus their arrivals are in the random state.

Katti and Pathak (6) has analysed various headway distribution models for urban roads under mixed traffic conditions. It was observed that opportunities for passing depend upon the width of the road and vehicle size, which has direct influence on the choice of the headway model.

According to Satish (7), the exponential and log-normal distributions are not able to describe headway distribution under mixed traffic conditions. The hyp distribution is found to be sound and quite versatile for this purpose and can be fitted to a wide range of traffic volumes.

The case study of time headways from Riyadh by Ali-Ghamdi (8) indicate that though observed headways at arterial sites follow a Gamma distribution, distributions that fit freeway headways differ according to the traffic flow state. The Erlang distribution provides a good fit to the observed headway at sites with high traffic flows.

The studies so far made for heterogeneous traffic flow do not clearly indicate the characteristics of headway pattern. Also the concurrence flow of several types of vehicles was not studied in detail. Hence in this study, an in depth study and analysis of headway distribution are made to have a better understanding.

III. Data Collection

The data for the present study was collected at ten mid block sections of four lane divided (2 lanes on either side) roads in Chennai city. The video recording technique was used to collect the data. A reconnaissance survey was done initially to select the site. The mid block stretches selected were straight, level and free from any obstructions/restrictions to traffic movement. There were raised foot path on either sides and the divider was fixed.

The road stretches were selected so that the carriageway widths varied from 6.5 m to 9.0 m. ie, + /– 1.5 m of the standard two lane urban road of 7.5 m. The road links were identified based on the traffic and their characteristics. To have a good representation of the whole study area, i.e. the Chennai city, the road stretches were selectively chosen from the three parts of the city ie. South, North and Central. Based on the city road map and discussion with experts, the first list of locations was drawn. A reconnaissance survey of all the road links was made to see the actual site conditions and the geometrics. The exact survey locations were frozen after ascertaining that the flow is even and the stretch is divided for a substantial length without any obstructions like bus stops, signals. The video recording technique was used to collect the data. The place for fixing the camera was also selected. A longitudinal trap length of about 30 m was adopted to capture the data for the measurement of speed. Markings were made with paint on the road to fix the trap length. The video camera was mounted on the tripod stand and was placed at a sufficiently high level so as to cover the full survey stretch. The data collection was done on normal sunny days (working days between Mondays through Friday). The surveys were carried out for 5 hours between 7 am and 12 noon, sufficiently long duration to cover both peak and off peak traffic. The timer in the camera was switched on to have the time recorded. In addition to the traffic data the physical data like carriageway width, footpath width, and adjoining land use were collected at the survey locations.

IV. Data Synthesis

The data collected at the site on video tapes were converted into video files and copied on to a CD. Using the “Timeint” computer programme, which records the arrival of the vehicle at the section at the stroke of a key, the inter arrival time was recorded up to 2 decimal places of a second and stored as file. The CD was run several times for creating volume/headway data files for the entire survey period for each category of vehicle. Counts were classified as heavy vehicles (lorry and tankers), buses (both private and metropolitan public transport buses), LCV (van and maxi cabs), cars, autorickshaws, powered two wheelers and cycles (including other slow moving vehicles). Using a stop watch the time taken by each category of vehicle to pass the road stretch marked at the survey location was recorded by running the CD several times for the entire survey period. The data for speed estimation was analysed for sample data, of not less than 25 percent of the total volume, to get the average speed of the traffic stream and for each category of vehicle in each five minute time interval.

Since the peak traffic on Indian urban roads are high with varying categories, and as they do not follow lane discipline, all the vehicles are free to use the available road space. There is probability of more than one vehicle crossing the reference section at the same time, indicating that the headway is zero.

The road names, carriageway width, peak hour, peak hour traffic (Nos. and PCU) are given for all the 10 survey locations in Table 1. The traffic compositions at these locations are given in Table 2. The percentage share of motorized two wheelers was found to high varying from .. to ..

Most of the studies done on analysis of headway distribution have examined vehicular flow in the range from 400 vph upto a maximum of 3000 vph only. However the traffic volume on the selected roads (four lane divided) in Chennai during the peak hour varies from 3186 to 9975. The average headway (of all vehicles) at the 10 locations during the full survey period is shown in Figure 1.

To anlyse the data, the Bestfit statistical windows programme was used. For the given data set the software finds the distribution that fits best. More than 25 different distributions are tried to determine the distribution that best fits the data. It performs three standard tests to determine goodness of fit: Chi-square, Anderson – Darling and Kolmogarov – Smirnov.

The peak hour headway (inter arrival time) data of all vehicles were fitted for evaluating the most appropriate distribution. The total data obtained from the field were fitted to get the best distribution. As suggested by Chang and Kim, the headway data set was grouped in appropriate class intervals and the cumulative distribution done. The headway data above 95 % of the cumulative distribution were removed to eliminate long headways. The software was run for each location data set and the distribution which fits the data under both the conditions (with all data and without long headways) was obtained. Table 3 gives the best fit distribution model at all the ten locations – under both conditions. It is found that except for two locations there is variation in the selected distribution model for the headway data.

V. Analysis of Results

It is seen that there is no particular distribution model that fits for all the volume / headway. For the lowest peak hour flow of 3186 vehicles (on Mannarsami Koil Road), the headway was found to follow Inverse Gauss distribution model and for the highest peak hour flow value of 9175 vehicles on Anna Road, it was found to have a Triangular distribution model. The value of the distribution parameters and the salient statistical details of the distributions at all the selected locations are shown in Table 4.

Since there is no single distribution that fits the data at various locations, it was decided to analyse the best three fittings for each location. Table 5 shows the best three distributions that fits the data. It is seen that out of 10 locations, the headway at 7 locations reasonably follow Log Normal 2 distribution and at 5 locations the Inverse Gauss distribution is also found to be acceptable. For location 3, the Inverse gauss distribution is acceptable and for the other two locations (location 5 and 7), the exponential distribution was found to be acceptable. Hence, it is seen that for high volume traffic flow, the following three distributions are found to be acceptable: 1. Log normal 2; 2. Inverse Gauss and 3. Exponential.

Since the volume of flow is very high on most of the road stretches, it was decided to analyse the data for individual category of vehicle. Even though the segregation will not give the real headway of the traffic stream, this analysis will help us to examine the inter arrival time of each category of vehicles in the high volume traffic flow.

Hence, in this study, it was decided to segregate the data for each category of vehicles. The headway for all the seven categories of vehicles (lorry, bus, light commercial vehicles, car, autorickshaws, motorized two wheelers and cycles, including other slow moving vehicles) was extracted independently.

The peak hour inter arrival time data of the 7 data sets (bus, lorry, LCV, car, autorickshaw, motorized two wheeler and cycle) were arranged in ascending order and classified under time interval to draw the cumulative distribution. The data above 95 % of cumulative frequency were discarded to remove long inter arrival time. This data set was tried independently for each of the 10 locations. The data set for Bus, Lorry and LCV's were small when compared to other categories of vehicles. Also, the three categories of vehicles are large sized. Hence it was decided to combine the three categories and fit the data set. The average headway of each category of vehicles at the 10 selected locations is given in Table 6. The best, second best and the third best distributions for each data set separately and for all the ten locations were obtained and are tabulated in Table 7.

Analysis of the seven individual category of vehicles indicate that the Inverse Gauss distribution is found to be the most appropriate type for Bus (7), Lorry (5), Car (9) and Autorickshaws (8) headways. LCV and Cycle headways have equal chances of having either Exponential (8) or Pearson II (9) type of distribution. Triangular distribution was observed in 8 out of 10 locations for Two wheeler headways.

When the headway data of low volume and similar type of vehicles (Bus, Lorry and LCV) were grouped, the Inverse Gauss and Beta General distributions were found to be equally appropriate (8).

Even though all the road sections were four lanes divided, the width of the carriageway varied at each location. It is felt that the lane/carriageway width,

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volume and the distribution will have to be studied further to examine the reason for a variety of distribution.

VI. Conclusions

It was observed from literature that the headway of vehicles for high volume heterogeneous urban mid blocks have not be examined in detail.

It is found that there is significant variation in the distribution type between the full data and the trimmed data (95% cumulative data after removing small number of long headways).

The headway distribution is random and do not follow a set distribution. 3 different types of distributions, ie, Log Normal 2, Inverse Gauss and Exponential, were found to fit the data at 10 different but similar road stretches.

For high volume traffic flow, segregated flow / headway analysis will be more appropriate, combining small volume of similar vehicle types (Bus/Lorry/LCV).

The distribution of individual vehicle arrival will help to understand the flow / arrival better, where the volume is more and the traffic is heterogeneous and do not follow lane discipline. These micro details can be used effectively for simulation studies for capturing the traffic characteristics better.

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Table 1 : Width and Peak Hour Volume Details at the Survey Locations

Road name	Location No.	Carriageway Width (m)	Peak Hour	Peak Hour Volume in Vehicles	Peak Hour Volume in PCUs.
East Coast Road	1	6.5	8:30 – 9:30	3993	3733
Gandhi Mandapam Road	2	7.5	9:00 – 10:00	5021	4134
Sardar Patel Road	3	8.5	8:45 – 9:45	6252	5090
Anna Road	4	8.9	9:00 – 10:00	9975	8879
Ashoknagar IV Avenue	5	8.5	8:45 – 9:45	4346	3599
Arcot Road	6	7.45	8:45 – 9:45	7079	6091
Medavakam Tank Road	7	7.1	9:00 – 10:00	6370	4929
Periyar Road	8	8.6	9:45 – 10:45	5694	6085
Manarsamy Koil Road	9	6.7	9:00 – 10:00	3186	3360
North Beach Road	10	6.5	9:15 – 10:15	4330	4327

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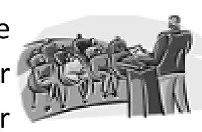

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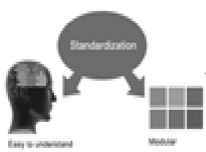

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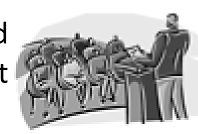

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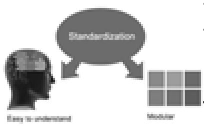

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2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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