Urban densification and the Compact model
6thSASTech 2012 Symposium

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Reference Number: 6-12-1-100

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Abstract

The aim of this study is to present software that permits the dimensioning of an urban densification. The model is based on the modeling of the functions and the corresponding spaces into an orthogonal parcel having a planar form. The elaboration of this tool is a response to a demand from the Department of the Housing and the Urbanism, which wants mastering the sustainable urban development.

The study begins by the identification of the urban functions and their correlations with the urban space. The summation of all spaces that compose the parcel defines the total area called plot area. The space of road into the system is a correlation of the shape, and of the disposition of the plots, and of the number of plots into the Plan. The urban composition is characterized by a mathematical system composed by two equations represented respectively by the urban density and the site coverage ratio. This system is undetermined because there is one unknown quantity: the total plot surface that depends of the road surface. To solving this problem, it is demanded to use the finite difference method.

Finally, the work ends by the presentation of the graphs illustrating the urban characteristics and the demonstration of software.

Key words: densification, functions, spaces, model, characteristics, software

1. Introduction

Today, 60% of the Algerian population lives in urban areas and more than half live within the 20 largest cities. Algerian cities and towns now account for over 50% of our national agricultural area and this reality is a great problem for the urban development. This paper describes a model design for urban development and redevelopment that will significantly reduce urban area consumption and enable all Algerian cities to become more sustainable communities. The authors Ladd (1992) and Peise (1989) insist on the fact that the challenge is to anticipate the future demands in urban growth by a sustainable development that takes in account the term vision. It is expected from municipal officials, planning commissioners, planners, architects, and private developers interested in building urban communities an improvement of living environment. According to Wendell (1993), the urban sprawl is guided by the criteria of financial affordability, accessibility and distance to the urban center.

The knowledge of the functions and space ratios, according to Nelson (1997), needs investigations on the rules and code of construction and town planning. If there are not values, then the approach is based on the real cases in uses. The urbanism is a multidisciplinary and interdisciplinary science. The Harlem Dictionary (1999) defines the urbanism as the art of the urban composition that has for finality the best organization of the functions and the social relations. The study can concern the design of a new urban project or a restructuration of an old urban zone. The present study is limited to a new urban composition based on the plane and orthogonal form. The urban composition is an optimized operation and it has for aim the rationalization of the space in according some criteria of viability. Density is one of the most used dimensions to assess urban sprawl. This affirmation is illustrated in specialized and popular literature as Cohen (2006) and show that sprawl became a metaphor for a model of suburban and urban expansion. The urban growth and sprawl and the environmental risks in Algerian is like the others urban agglomerations in the Africa or the Brazil. According to Ojima (2006), this urban growth generates urban risk and requires a new approach in the future urban design. For to enhance the design of the urban densification, Migayrou (2008) proposes, a model and a methodology for to enhance the future living in the City. The model is based on the analysis of the functions and the corresponding spaces into an urban space. The modeling process is a preliminary phase in the elaboration of tools. For each identified function, it is demanded to define its space. Often, for several functions, there is one space. In this case, one has a multifunctional space. The study can concern the design of a new urban project or a restructuration of an old urban zone.

2. **The Urban densification process**

2.1 Identification of functions and spaces

The concretization of the goal is based on the linear way of the design process of the urban composition. This approach needs to know the divers phases during the urban design. The beginning of project is very important. The engagement of all actors is required. There are three phases: Master plan, Plan of mass and detail plan. For any phase, there is adequate specialist, and the planer town is the driver of the staff. The correlation between the functions and spaces can schematize by the figure1.

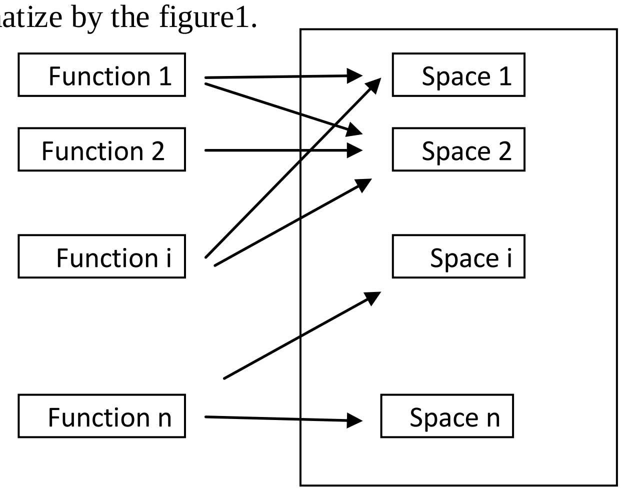

Figure 1: Correlation between functions and spaces in the urban composition.

2.2 The land or space

The Algerian manual of urbanism and construction M.U.C., (1989), the books of Zeitoun (1997) and Zucchelli (1983) permit a freely urban composition based on general information and orientations. The results of the urban characteristics are known after drawing. The works of Author El kechebour (1997 and 2010) enhance the design by the introduction of the automatic calculation that gives results by simulations.
The ratio space affected to any function varies according to the facilities, the moment or time and the cost of land. The dilemma for any actor of the planning town is to solve the equation composed of: land cost, land ratio and viability.
If the cost of land is very low, the urban density is weak. In the inverse case, the density is high. This affirmation is confirmed by the practice in the great metropolitan towns.

2.3 Formulation of the problem

The urban composition operation is realized by using two coefficients: the dwelling density (d) and the site coverage ratio (S.C.R). These coefficients compose a system that defines an urban density. The density shows the number of dwellings setting on a hectare area (10000 m2). In this area there are all spaces with their functions. The site coverage ratio (S.C.R) shows the organization of the buildings and the dwellings in the vertical and horizontal plan. The using of these coefficients can be applied for two scales: one building or one plot (mass plan).
For one building, the system is following:

$$\begin{cases} d = \dfrac{N}{Ass} 10000 & (1) \\ S.C.R = \dfrac{E}{Ass} & (2) \end{cases}$$

d: dwelling density
S.C.R: site coverage ratio
N: Number of dwellings on the area of the site.
E: Building footprint
ass: building compound.10.000 m2: hectare surface.
For one plot, the precedent equations (1) and (2) write on this form:

$$\begin{cases} d = \dfrac{N}{\sum ass} 10000\, m^2 = \dfrac{N_T}{ASS} 10000\, m^2 & (3) \\ S.C.R = \dfrac{\sum E}{\sum ass} = \dfrac{m * E}{m * ass} = \dfrac{E_T}{Ass} & (4) \end{cases}$$

m: Number of buildings (same type),
ASS = m.ass: building compound of the total plot area
E_T = m.E : Total surface of the Building footprint.
The building area is the surface that receives a building with all accompaniment areas. For the plot scale, the building area is the sum of all surfaces.
The building compound is the surface of the building without accompaniment areas. The sum of all building compound is equal to the total surface of the building compound.

The system formed by two equations, (3) and (4), and tree unknowns (N_T, E_T and Ass) gives infinity of solutions because it is undetermined. In the practice, the problem of the third unknown is resolved because the urban form is fixed (use of plan).
Physically, the operation of the urban composition consists in the setting of masses on an area, and the ratio masse/space is the criteria that permit to give estimation on the urban density (big or weak density). The real surface of the area site is determined after the design of plan.
The operation is qualified optimized if the volume of plot is equal to the volume determined by the calculus. In this case, the operation corresponds to a mathematical relation called: "strict equivalence". In the opposite case, the operation is partially optimized and it is called: "correlation".

2.4 The size of Street

The dimensions of the street are a correlation of these factors: number of plots (urban size), setting mode of the plots, and the form of the plots.

- *Road length according to the number of plots*

The total length of road is fixed by the number, the shape and the setting mode of the plots. The determination of the length of an urban shape, composed of many plots, that has trellis form is based on the assumptions:
Square plot (identical) = 1 Hectare
Number of floor = n
Dwelling density = constant,
Number plots = i,
Number lines = j,
LVT = total length road,
l = length of one square plot.
The summation of all lengths gives the following result:
LVT =(2i + 2) l/i = 2l(1 + 1/i)

$$\lim L_{VT} = 2l \quad (5)$$

- *Road length according to the shape of parcel*

The length of the total road (LRT) changes in according to the perimeter of the plot.
k= LT / lT (6)
d = (NT/Ass).10000
Ass = 10.000. N_T/d (building compound)
= LT.lT = (k . lT)lT = k.lT2
LRT = LT + lT = k . lT + lT

$$L^2_T = \frac{1000N_T}{k.d}$$

$$\text{Then} \quad L_T = \frac{100}{\sqrt{k}}\sqrt{\frac{NT}{d}} \quad (7)$$

$$L_{RT} = k\frac{100}{\sqrt{k}}\sqrt{\frac{N_T}{d}} + \frac{100}{\sqrt{k}}\sqrt{\frac{N_T}{d}}$$

$$= 100\sqrt{\frac{N_T}{d}}(\sqrt{k} + \frac{1}{\sqrt{k}}) = 100\sqrt{\frac{N_T}{d}}K_f \quad (8)$$

$$Kf = \sqrt{k} + \frac{1}{\sqrt{k}} \quad \text{(coefficient of the form)} \qquad (9)$$

The length of the total road (L_{RT}) is formulated by the relation (8). The figure 2 shows the values of K_f. The length of the total road (LRT) is determined by recurrence according to the setting mode of the plots. The relations (10) and (11) illustrate this length.
i: total number of plots.
r : number of lines (ranges).
i/r : number of plots by lines

$$L_{RT} = l_T[\frac{(r+1)k}{r} + 1 + \frac{r}{i}] \qquad (10)$$

$$\lim_{\substack{i\to\infty \\ r\to\infty \\ r\ll i}} L_{RT} = \lim_{\substack{i\to\infty \\ r\to\infty \\ r\ll i}} l_T\left[\frac{(r+1)k}{r} + 1 + \frac{r}{i}\right] = l_T(k+1) = L_T + l_T \qquad (11)$$

The total length of road is a correlation of the plot form, the number and the disposition of plots.

$$L_{RT} = l_T\left[\frac{(r+1)k}{r} + 1 + \frac{r}{i}\right] = T * (L_T + l_T)$$

$$T = \frac{l_T\left[\frac{(r+1)k}{r} + 1 + \frac{r}{i}\right]}{(L_T + l_T)} \qquad (12)$$

T: *coefficient of the urban size*

The total length varies between the values 1 at 2. The values of the coefficient of the urban size (T) are illustrated by the figure 3.

- *Width of street and Platform*

The length L_0 around the building is necessary for the servitude and it delimits the platform. It varies between 2 m at 3 m. The value A represents the width of the road and pavement depends on the urban density and the traffic of circulation. The values L0 and A are the result of a modeling process based on the values in use.

$$L_o = 3.5 - 2.7n \qquad \text{n: number of floor} \qquad (13)$$

$$A = 5 + 3\sqrt{n} \qquad (14)$$

- *Global area of road*

The total surface of road and pavement (SRT) for one plot is illustrated by the relation (15).

$$SRT = LRT * T * A = 100\sqrt{\frac{N_T}{d}} Kf * T * A \qquad (15)$$

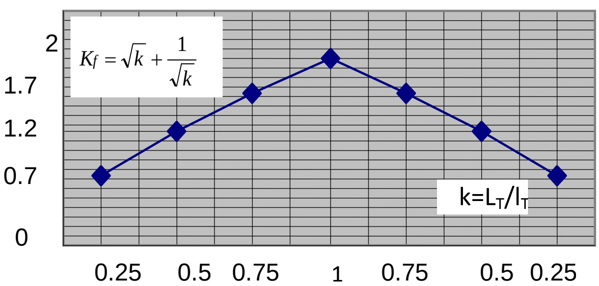

Fig 2: variation of coefficient of the form (K_f) according the ratio k =L_T/l_T

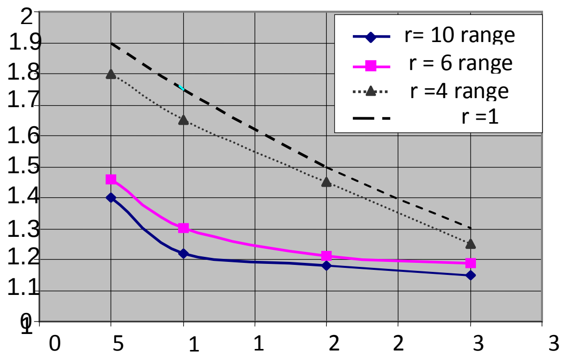

Fig 3: Graph of values of the urban size (T) according to number of plots (i) and number of lines (r).

3. Resolution Methodology

The choice of the plot represented by the figure 3 permits to vary freely the number of floors independently of the parking constraints and the distance between the opposite facades.

- *Presentation of the plot*

The solving concerns the plot illustrated by the figure 4.

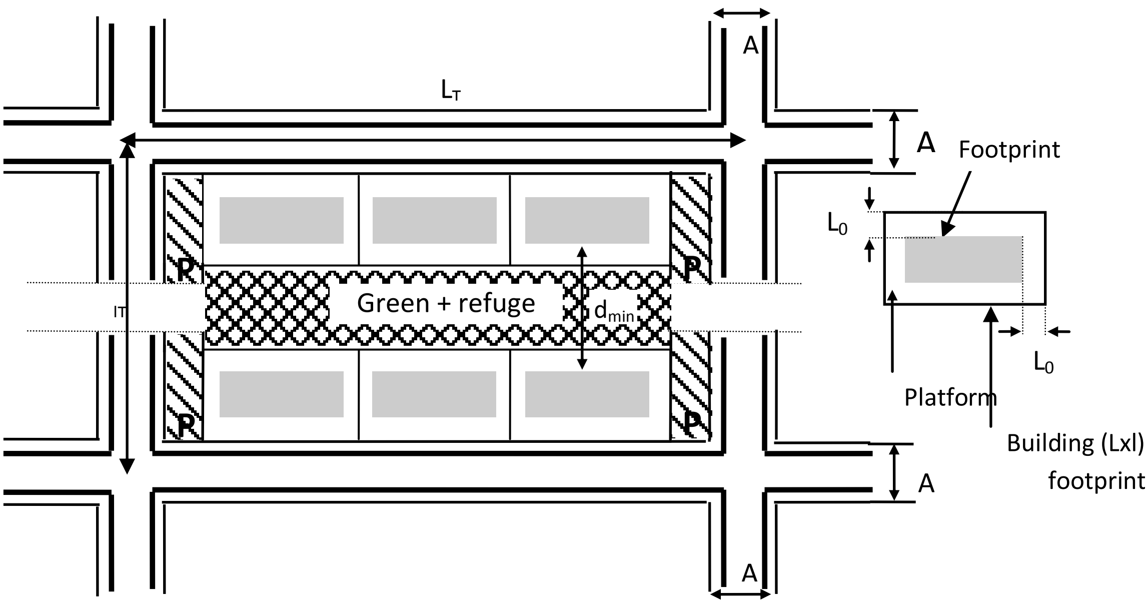

Figure 4: Schema of the model of the orthogonal plane plot with buildings footprint detail.

- *Inputs:*

e = 112.5 square meter (surface of one dwelling)
m = 8 (number of building into one plot)
L = 25 meter (length of building)
l = 10 meter (width of building)
x =2 (dwellings by level into one building)
y = 6 (number habitant into one dwelling)
Kv =1 number of car (vehicle by dwelling)
sev = 5 square meter (surface green space + children games space for one habitant = area refuge)
Sst = 15 sqare meter (parking area by one car)
E = 250 square meter (building footprint)

- *Calculus:*

ass: building compound (total surface one plot)
N: number dwelling by building
Spf: platform surface of one building
L0: length around building
l_T : width of plot
L_T: length of plot
N_T: number dwellings in one plot
ASS: building compound of the plot
E_T: global Building footprint of the plot
ASS: Global surface of the plot
Spf_T : Global surface Platform in the plot:
dmin: minimal opposite distance between two builds

L_{VT}: global length of the plot
Sst: Global area for parking in the plot
Sev: Global area for green space in the plot

$l_T = 2(10 + L0) + dmin + A$

$L_T = 3(25 + 2L0) + A + Sst/l_T$

$Spf = (L + 2l0)(l + 2.l0)$
$Sst = Sst = sst . Kv . NT = sst . Kv . x . m . n$
$Sev = sev . NT . y = sev . x . y . m . n ;$
$E_T = m . E = m . x . e$
$Spf_T = m(L + 2.l0)(l + 2.l0)$
$= m[L + 2(3.5 - 2.7/n)][l + 2(3.5 – 2.7/n)]$

$ASS = SpfT + Sev_T + Sst + SV_T$
$dmin = 2L0 + Sev_T/[3(25+2L0)]$

- *Solution:*

The solution consists to solve, using finite difference method, the following system composed of equations (16) and (17):

$$\begin{cases} d = \dfrac{N}{\sum ass} 10000\, m^2 = \dfrac{N_T}{Ass} 10000\, m^2 & (16) \\ S.C.R = \dfrac{\sum E}{\sum ass} = \dfrac{m * E}{m * ass} = \dfrac{E_T}{Ass} & (17) \end{cases}$$

- *Verification:*

According to the recommendations of the urbanism office of the city of BLIDA and the department of urbanism and construction it is demanded to proceed to the following verifications:
Distance between principal facade ≥ H/2
Distance from axis of road to the platform of building ≥ H/2
Width of the pavement ≥ 2 m
Minimal width of road ≥ 5 m
H: elevation of building.
These recommendations concern only the individual private suburb. For the design of the great operations, the specifications are referenced into the plan of the soil occupation.

4. Results and Analysis

1. Results

The resolution of this present plot (Fig 4) permits to determinate the urbanistic and geometric characteristics. The figures 5 to 7 show these characteristics in according to the number of level (n) and the coefficient of size (T).

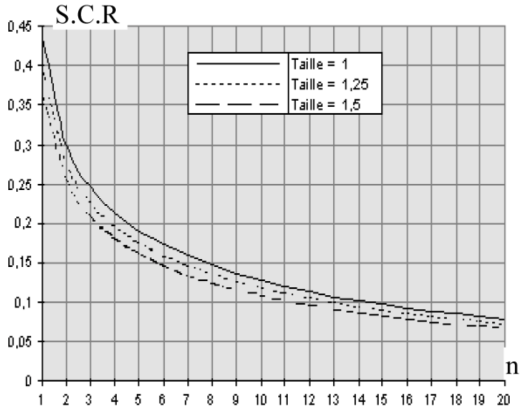

Fig 5. Graph of site coverage ratio (S.C.R) according the number of level (n) and the size (T).

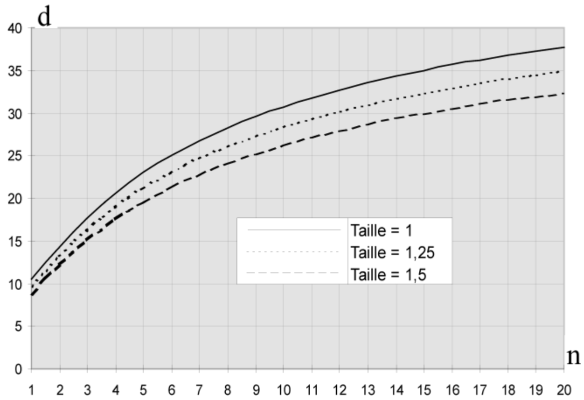

Fig 6. Graph of density (d) according the number of level (n) and the urban size (T).

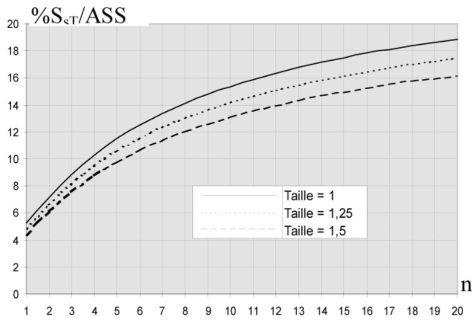

Fig 7. Graph of percentage parking area (%SsT/ASS) in one plot according to: the building compound (ASS), the level (n) and the urban size (T).

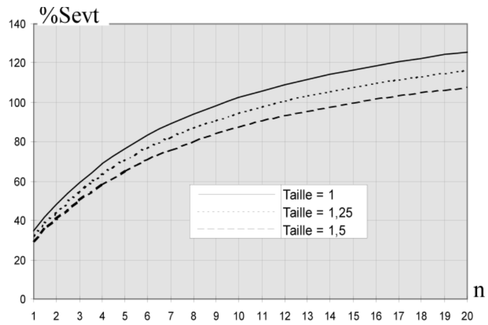

Fig 8. Graph of percentage of the green space with refuge area (%Sevt/ASS) in one plot according to: the building compound (ASS), the level (n) and the urban size (T).

2. Analysis

The length of the road necessary for one urban plot is a consequence from the design, and it is impossible to know this value beforehand. After the design plan, this value is known. The values determined by the present formulas give acceptable results in comparison whit real simulations cases. The errors established on the urban density (d) and on the site coverage ratio (S.C.R) are very little: 1% to 1.5% for the values n= 2; 0.5% to 1% for the values n= 3; and negligible for $n \geq 4$. Globally, the results obtained by simulations on the model, are considered by the town planers and the architects of national centre of urbanism and the urban office of the city of Blida, as acceptable for the little and middle urban composition. This conception permits to realize a multifunctional area: area for baby games, area for green space and area for seismic refuge. In the seismic zones, the area refuge necessary against the seismic risk in the urban zone is not easily acceptable because the cost of the land is very expensive. This constrain is mitigate if the area refuge is integrated as green space situated between the buildings.

It is recommended to adopt for the urban densification, in seismic zones, the following values: two (2) m^2 for children games space and six (6) m^2 for the green spaces. The total area refuge of these values corresponds to a distance between two facades equal to the twice elevations (2H) of building. It is preferable to take this minimal distance like multifunctional refuge area.

5. Conclusions

The mastering of the planar orthogonal plot is a necessary phase in the global design. Indeed, any urban plot can to be reduced to a planar orthogonal plot.

In conclusion, it is established that the urban densification founded on the functions and spaces permits to simulate a quantitative estimation of the building footprints and the others areas that compose the urban land. The compact model gives an optimal urban network and a concentration of urban amenities. For to avoid the urban sprawl, this approach is compatible with the sustainable urban development vision proposed by Young (1995). The present model is opened for others implementations areas, and the mathematical approach is benefic for the automatic calculus.

Acknowledgements

The author thanks the colleagues of the urban planning of city BLIDA and Pr. Jacques Teller of Liege University (Belgium) for have given their views on this approach concerning the urban densification.

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