Modelling of Road Space in the Design of a New Urbanization

Boualem El Kechebour and Ammar Nechnech

Abstract—**The goal of this study is to present a tool that permits to reduce the time of design and to obtain a quantitative assessment of the road space. The model is based on the modelling of the functions and the corresponding spaces into an orthogonal parcel having a planar form. The elaboration of such as tool is a response to the sustainable urban development that preconizes the optimization of land use. The summation of all spaces that compose the parcel defines the surface called plot surface. The space of road into the parcel is a correlation of the shape and of the disposition of the plots, and of the number of plots in the urban 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 indeterminate because there is one unknown: the building footprint; and one correlation: the plot surface. To solving this problem, it is demanded to use finite difference method. At last, the graphs illustrating the road ratio, the urban features and the software are presented.**

Index Terms—**Modelling, urbanization, road space, urban density, urban sustainable development, software.**

I. Introduction

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. It is intended for municipal officials, planning commissioners, planners, architects, and private developers interested in building urban communities that are more livable than existing communities. The challenge is to anticipate the future demands in urban growth [1], [2] and [3].

The knowledge of the functions and space ratios needs investigations on the rules and code of construction and town planning [4]. 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 urbanism is the art of the urban composition that has for finality the best organization of the functions and the social relations [5].

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 [6] and show that sprawl became a metaphor for a model of suburban 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. This urban growth generates urban risk [7] and requires a new approach in the future urban design [8]. It is necessary to propose, for to enhance the design of the urban composition, a model and a methodology. The model is based on the modelling of the functions and the corresponding spaces into an orthogonal parcel having a planar form.

Manuscript received November 3, 2012; revised December 24, 2012. This work was supported in part by the Algerian Department of Urbanism.

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A. 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. 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 Fig.1.

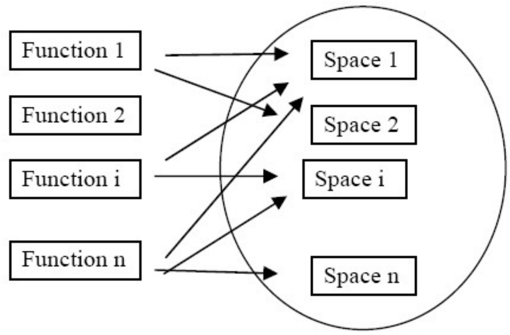

Fig. 1. Correlation between functions and spaces in the urban composition

B. The Land or Space

The elements permits a freely urban composition are cited in the following references: the recommendations of the Algerian manuals of urbanism and construction [9], the books of Zeitoun [10], Zucchelli [11]-[12] and the works of Author [13]. The information can to be obligatory as norm or standard, and can to be only for orientation.

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.

C. Formulation of the Problem

The urban composition operation is realized by using two

DOI: 10.7763/IJET.2013.V5.531

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:

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

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:

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

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 an mathematical relation called: “strict equivalence”. In the opposite case, the operation is partially optimized and it is called: “correlation”.

D. 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.

1) Total length of road in the plot and final urban size: 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 =(2*i* + 2) l/*i* = 2l(1 + 1/*i*)

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

2) Length of the total road and form of the plotThe length of the total road (LRT) changes in according to the perimeter of the plot.

$$k = LT / lT \quad (6)$$

$$d = (NT/Ass).10000$$

$$Ass = 10.000.\ N_T/d \quad \text{(building compound)}$$

$$= LT.\ lT = (k\ .\ lT)lT = k.lT2$$

$$LRT = LT + lT = k\ .\ lT$$

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

$$LT = \frac{100}{\sqrt{k}}\sqrt{\frac{NT}{d}} \quad (7)$$

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

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

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

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

The length of the total road (LRT) is formulated by the relation (8). The Fig. 2 shows the values of *Kf*. 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

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

$$T = \frac{l_T\left\lfloor \frac{(r+1)l}{r} + 1 + \frac{r}{i} \right\rfloor}{(L_T + l_T)}$$

$$L_{RT} = l_T\left\lfloor \frac{(r+1)k}{r} + 1 + \frac{r}{i} \right\rfloor = T\times(L_T + l_T) \qquad (12)$$

T: coefficient of the urban size

The total length varies between the values 1 at 2. The values of the coefficient T are illustrated by the Fig. 3.

3) Width of street and Platform

The length L0 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.

$$L_o = 3.5 - 2.7n \qquad (13)$$

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

n: number of floor

4) Global area of road

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

$$S_{RT} = L_{RT}\times T\times A = 100\sqrt{\frac{N_T}{d}}K_f\times T\times A \qquad (15)$$

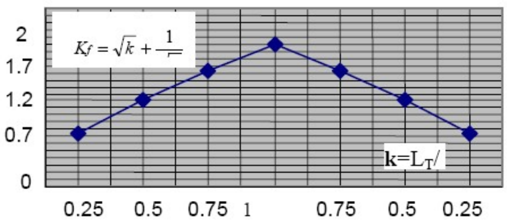

Fig. 2. Variation of coefficient of the form (Kf) accordingthe ratio k =LT/lT

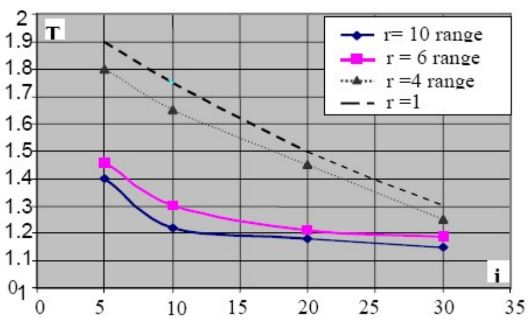

Fig. 3. Graph of values of the urban size (T) according the number of the plots (i) and the number of the lines (r).

II. Solving of The System

The organization of all spaces is submitted to the coherence of assigned functions and to the constraints of implantation on a real site. The choice of the plot represented by the Fig. 3 permits to vary freely the number of floors independently of the parking constraints and the distance between the opposite facades. This present composition of space is inspired by the recommendations mentioned in the manual of the urbanism (M.U.C. 1989).

III. Solution

The solution consists to solve the following system composed of equations (16) and (17):

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

IV. Results and Discussion

A. Results

The Fig. 4 to 8 show the urbanistic and geometric characteristics in according to the number of level (n) and the coefficient of size (T).

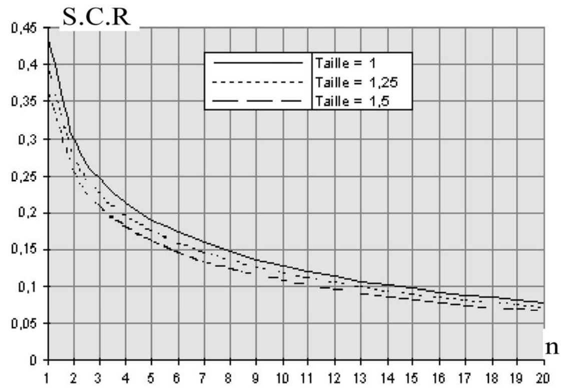

Fig. 4. Graph of site coverage ratio (S.C.R) according the number of level (n) and the size (T).

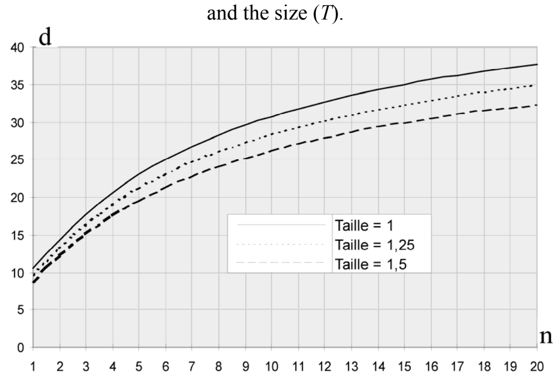

Fig. 5. Graph of density (d) according the number of level (n) and the urban size (T).

B. Discussion

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 ≥ 4. Globally, the results obtained by simulations on the model, are considered by the town planers of national centre of urbanism like acceptable.

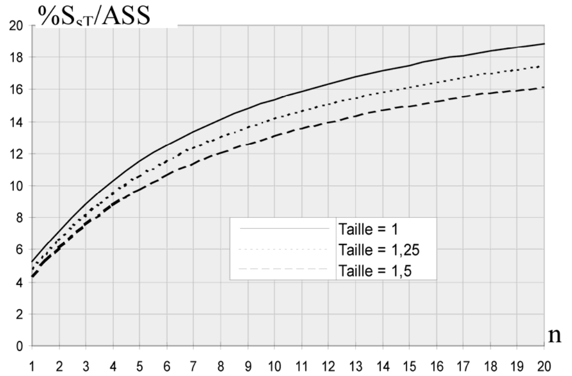

Fig. 6. Graph of percentage parking area (%SsT/ASS) in one plot according: the building compound (ASS), the level (*n*) and the urban size (*T*).

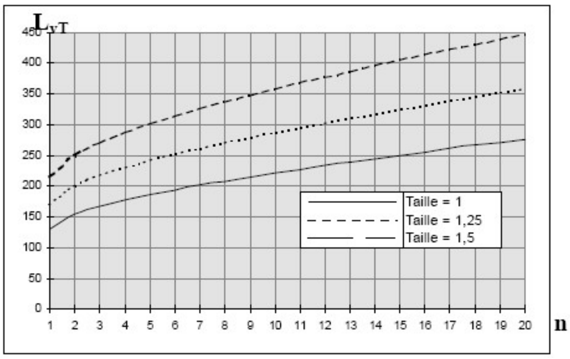

Fig. 7. Graph of the total length L_{vT} of road according the of level (*n*) and the size (*T*).

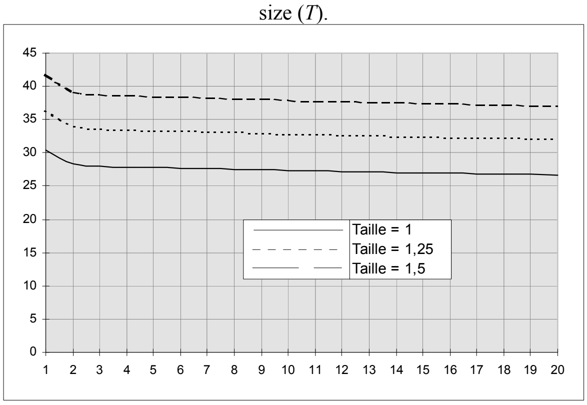

Fig. 8. Graph of the total area L_{vT} of road according the number of level (*n*) and the size (*T*).

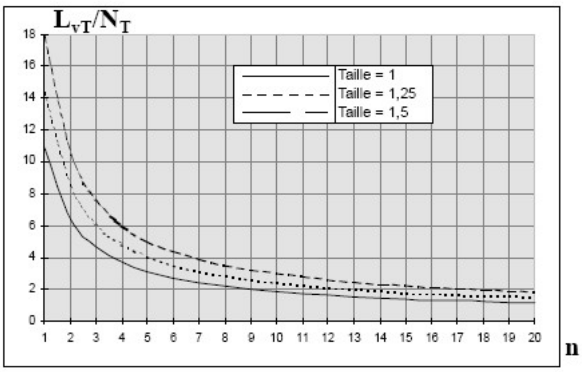

Fig. 9. Graph of the ratio length L_{vT} of road according the global number of appartments, the number of level (*n*)

V. Conclusion

The mastering of the planar orthogonal plot is a necessary phase in the global design. Any urban plot can to be reduced to a planar orthogonal plot. The area road necessary in the urban zone is not easily acceptable because the cost of the land is very expensive. This constrain is mitigate if the area parking is integrated like trade space during the day. The model is opened for others implementations areas and the mathematical approach is benefic for the automatic calculus. This study is a contribution for a new approach on the urbanism based on the functions and spaces permitting to simulate a quantitative estimation of land area in according to the vision of the sustainable urban development [15].

The adopted demarche has permitted a modeling for a dynamic case. In the practice, the static evaluation based on a real master plan is used.

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