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Jakub Onyszkiewicz, Agata Woźniczka

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Tools and Methods for "Quantifying" Urban Liveability:
two Parallel University Teaching Experiences

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ABSTRACT: The paper describes a specific educational experience carried out at two Italian universities within distinct academic programs.
At the Politecnico di Milano, within the School of Architecture AUIC, an architectural design studio was held with the aim to identify urban regeneration opportunities near to an area undergoing significant enhancement and repurposing. Meanwhile, at the Faculty of Computer Science at the University of Turin a course in a master's program on Digital Innovation for Living Environments, introduced students to spatial environments with diverse functionalities. The students analysed these environments to identify ways of supporting user needs through digital and innovative technologies. In both cases, spaces within public and private buildings, and urban spaces, were considered. Students were involved in qualitative and quantitative assessments of urban spaces' livability using a methodology based on the approach developed by the Barcelona Ecology Agency (AEUB). This approach aimed to synthesize, with a single indicator, the blend of qualitative and quantitative aspects contributing to the attractiveness and environmental well-being of places.
KEYWORDS: Urban liveability index, Public space, Tools & methods, Computing sustainability

1. INTRODUCTION

The paper describes a specific educational experience at two Italian universities within distinct academic programs driven by a shared goal of promoting sustainability evaluation for urban spaces. These programs can converge in transdisciplinary approaches and methods to enhance the implementation of strategies and tools aimed at improving livability in both existing and newly developed urban environments. A semester-long architectural design studio was held at the Politecnico di Milano, within the School of Architecture AUIC. Its objective was to identify opportunities for urban regeneration of the site around the Porta Romana Rail Yard in Milan. A significant part of the design process presented to student groups involved assessing, including quantitatively, the livability of public and urban spaces using a methodology derived from the approach implemented for many years by the Barcelona Ecology Agency (AEUB). During the same semester, a course on Digital Innovation for Living Environments was conducted at the Faculty of Computer Science at the University of Turin. This course, offered within the master's program, introduced students to spatial environments with diverse functionalities. The students analyzed these environments to identify ways of supporting user needs through digital and innovative technologies to enhance environmental conditions and livability. Spaces within both public and private buildings, as well as open spaces, were considered. During this course, the indicators from the AEUB were introduced, and methodologies and digital tools (i.e., customized codes) were developed to calculate the livability indicators. These tools are aimed at supporting the assessment of various elements contributing to the quantification of spatial quality and the degree of livability in public spaces.

2. TOOLS AND METHODS FOR "QUANTIFYING" URBAN LIVABILITY

A common ground between the educational activities conducted in the Architectural Design Studio for future architects and those for future computer scientists lies in the necessity to translate a concept, often exclusively qualitative, into a numerical indicator to compare different conditions (before and after a project, different spaces, design options, etc.). This process aims to identify the best acceptable solution while considering the various aspects of the urban realm.

When the concept of livability is concerned, it can be defined as the combination of a number of variables [1], including safety, sustainability, environmental comfort, services, walkability and public transport, which can generate different livability conditions. In this context, the livability concept meets the users’ needs without sacrificing the functionality requirements of the spaces. The sustainability challenge is quantifying exquisitely qualitative aspects, such as the architectural quality of a space or its attractiveness, which is crucially important as it would allow us to consider all aspects in the overall evaluation of an area. It is hence interesting how the contribution of computer science comes in support of automizing the process [2] of quantification. It defines a possible objective assessment structure that would otherwise be subjective and naive. The evaluation approach, developed by the AEUB, aims to synthesize, in a single indicator, the blend of qualitative and quantitative aspects contributing to the attractiveness and environmental well-being related to urban spaces [3,4]. All measurements are standardized on a score scale from 1 to 5 to combine the different parameters (1 is the worst, 5 is the best condition). In some cases, it is pretty easy to translate a value, like the thermal comfort indicator, in a score scale from 1 to 5. In other cases, it is more complex, for instance, when we need to evaluate the impact of the greenery in terms of attractiveness or the effect of the suited mix of commercial activities.

2.1 The work of the Architecture students

It is increasingly important to clarify to architecture students involved in designing livable, attractive, and sustainable urban space that the city is a system that integrates many aspects at different levels and that the design is the synthesis of acceptable solutions that the systemic, and therefore complex, vision poses, which often require different points of view, approaches and skills. The approach of the AEUB is particularly intriguing, as it considers 9 indicators to calculate urban space livability, plus additional 3 indicators for estimating the livability of the surrounding urban area of the selected public space (Table 1). The categories of parameters considered are:

1. Ergonomic characteristics;
2. Attractiveness;
3. Environmental features.

The additional three parameters used for calculating the:

4. Surrounding livability are:
   - Number of services (i.e., schools, clinics, libraries, etc.) within a 300-meter radius;
   - Number of daily-use commercial activities within a 300-meter radius;
   - Number of public transportation networks within a 300-meter radius.

Table 1 lists the parameters considered for the liveability assessment; the first 9 only related to a specific space, while the 12 parameters assess the liveability at urban level.

Although the AEUB methodology was adopted for data collection and the final indicator calculation, in the case study selected by the architecture students, adjustments were made to adapt it to specific contexts and the availability of open data in the City of Milan [5]. This occurred, for instance, in assessing the best dimensional ratio, such as the view of the sky from the streets or the evaluation of functional mix and thermal comfort.

Table 1: Parameters considered for the liveability assessment.

Parameters	mu	How to assess
1.1 Pedestrian/vehicular areas ratio	%	Proportion between pedestrians and the whole area
1.2 Accessibility	%	Sidewalk wideness and slope
1.3 Dimensional ratio (H/D; SVF)	Deg	Degree of Sky View factor
2.1 Functional mix	Bit	Shannon formula
2.2 Attractivity	N.	Typology of activity
2.3 Green volume	%	The ratio between green volume and the street volume (below 8m)
3.1 Thermal comfort	n. hours	The number of hours of t. comfort
3.2 Acoustic comfort	Dec	Decibel level revealed with app
3.3 Air quality	NO_2;	Pollutant data available from open data

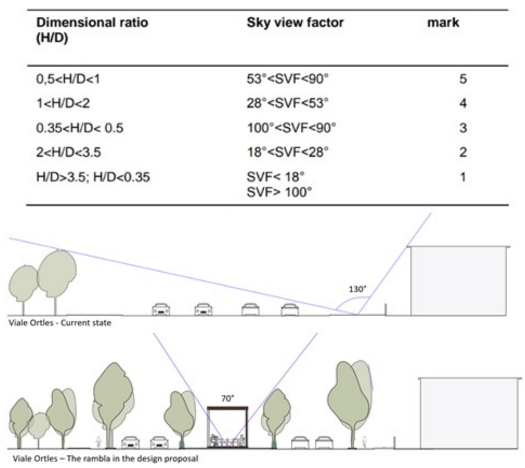

Figure 1: Table of correspondence of dimensional ratio and sky view factor of a street and score associated with different values, and below, two different sky view factor values of the same street, Ortles road at Milan, before and after a design proposal.

Although the students of Politecnico worked on all the parameters to define the liveability indicator, the paper reports the analysis of some aspects which were then analyzed by the students of University of Turin.

Among the works developed within the Design Studio, which aims to work within the city of Milan, an interesting case can be considered, in which the the location for evaluating the degree of livability of the public space focuses on a particularly significant road within the design strategy identified by the student's groups. The road, viale Ortles, in the southern part of the city, is a traffic-devoted space with very low quality from every point of view.

Nevertheless, it has the potential to be an important green corridor and an important arterial road that enables the connection of existing urban spaces and gardens.

Figure 2: The current state of Ortles road in Milan, Italy.

An accurate analysis of the area's current state is an integral part of the site knowledge process, preliminary to the project phase and necessary to assess the increase in the livability value achieved by the project proposal. One of the necessary elements to be investigated concerns the type of present plants (regarding bearing and height). Vegetation is an aspect impacting several parameters that contribute to the indicator calculation. In particular, in the section "attractiveness," we find the volume of greenery. At the same time, in the group of environmental variables, it is important mainly for thermal comfort but also air quality. Vegetation can also be considered as a design strategy to change the dimensional ratio of the street 1.3), at least from the point of view of perception of the vertical limits of the space. The volume of greenery parameter (2.3) is calculated by considering the section of the street, possibly divided into parts if the section or the size/shape of the trees changes, up to the height of 8 meters, which takes into account the real field of view of a person walking down the street. In the case of Ortles road in Milan, the analysis of the existing situation shows a relevant absence of vegetation, which is evident from Figures 1 and 2. The design proposal for vehicular traffic reduction and the livability and attractiveness enhancement of the street consists of a mix of actions, including the increase of pedestrian areas, new paved and vegetated surfaces, commercial activities and trees (considering the road section up to the height of 8 meters, from the 7% to 25%, i.e., from the score of 1 to 4). The street becomes a sort of "Rambla," where the green areas support different functions, including diverse types of plants characterized by specific shapes and sizes. Figure 3 reports the street and the facing built environment, the section with the line at 8 m high for the calculation of the percentage of green and the plan of the area. With the proposed renovation, final users are attracted to and can fully enjoy the improved livability from several points of view. The improvement due to the vegetation increase on the final score is very evident; for other parameters, the increase in the score is not so strong.

For example, the commercial activities on the ground floor of buildings facing the road (2.1) were weighted in terms of attractiveness (2.2), by those who worked with direct observations (e.g., site visits, Google Street map, etc.) and design analysis of plan instruments.

Figure 3: Design proposal for revitalizing the Ortles road in Milan that use an adequate number of trees in the central pedestrian area (the Rambla) and along the sidewalks.

The weight of each type of activity is performed as defined by AEUB, and it was calculated and averaged every 500 meters. The increase, from the initial score of 2.6 to 3, in the proposed renovation of the case study is due to the rise of some retail commercial activities within the Rambla, particularly ice cream kiosks, bars, and others in the buildings facing the road. The appropriate choice of both the types of activities and their location along the entire street axis also positively affected the diversity, the functional mix that ensures the presence of multiple users with different characteristics creates the livability of the area throughout the day. In this case, the calculation was done using the Shannon Diversity Index (2.1) formula, which calculates the bits of information based on the calculation of the types of activities present and their occurrence (1):

$$H = - \sum p_i \log_2 p_i \qquad (1)$$

where H is the Diversity (bit)

p_i is the proportion of the entire community made up of species i.

The higher the value of H, the higher the diversity of species (in this case, the attractive commercial activities in a particular location). According to the design proposal, the functional mix increased from 1.5 to 2.6. Considering the whole strategy, the road livability increases from 2.6 to 3.7.

2.4 The Work of Computer Science Students

In the case of the architecture students, the primary purpose was a design proposal to improve the livability conditions of the streets, while the computer science students focused on methods and tools to speed up and promote process automation in the evaluation procedure.

In fact, the computer science students collected data on the city of Turin as case study and developed specific methodologies and codes to support verifications related to the following indicators:

- Pollution/acoustic comfort;
- Presence of trees in surveyed areas;
- Percentage of green spaces;
- Quantity of commercial services;
- Diversity of activities in the test area.

These methodologies can also be applied to verify the following indicators:

- Air quality;
- Thermal comfort.

The students' activities primarily focused on collecting robust open data, enabling the identification of areas with acoustic pollution in the city of Turin, used as case study, and the mapping of existing trees in the urban area. They used an urban scale approach and then focused on district and street level. The use of open data allowed them to create maps for assessing critical areas and identify possible strategies for improving the situation [6], such as:

- Areas in need of traffic control;
- Acoustically critical areas that need specific strategies (e.g. limited traffic zones).

The analysis allows to define where to promote the creation of new green areas supporting city-level decision-making processes with key local policies.

The methodology is suitable for conducting a primary screening and general assessment of the conditions however, the precision and accuracy is reduced in specific streets where possibly some measurements can be required to define hourly scenarios.

Open data and the translation in maps of the acoustic risk have been implemented using digital tools and data available as open source (Figure 2). To assess the trees in the Turin area, the students used the Treepedia [7] of the MIT Senseable City Lab of Boston to obtain an image containing the different trees in the city. Through this open resource, they can obtain the approximate number of trees on different streets using a very robust source and implement the possibility to automate the task.

However, with this procedure, it is impossible to define the trees' and the tridimensionality. To overcome the first issue, the students developed a method to automate the process of counting the trees starting from the available open-source information (Figure 5).

For trees counting, an "image classifier" was developed using a code that takes an image of a street as input, allowing the calculation of the percentage of pixels corresponding to the trees. The RGB value of the pixels is considered. When the pixel has a value with a prevailing green color, it is counted as public green, allowing the percentage of green automatic calculation in the street (Figure 4).

Figure 4: Acoustic pollution map, city of Turin, Italy.

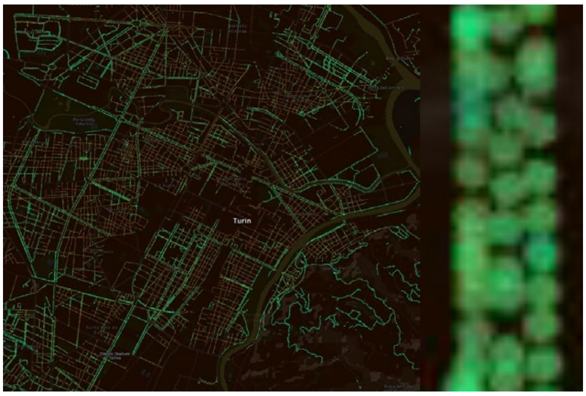

Figure 5: Map of the trees in Turin and Pixel analysis to detect the green areas and the number of trees through the image classifier in a street.

A possible future development uses the convolutional neural networks (CNN) to detect trees from images to include information related to the tridimensionality.

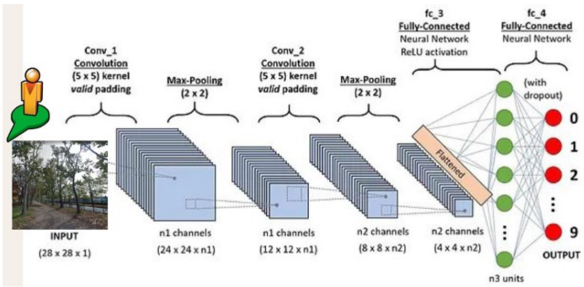

Figure 6: Scheme of the image recognition performed through neural networks (CNN).

To assess the value of the commercial activities and functional mix indicator, a python dashboard was organized to use the collected data, regarding all commercial activities in Turin through CSV files downloadable as open data. This dashboard enables filtering based on street or postal code. All the calculated indices can be visualized on an interactive dashboard. A customized code has been realized for extracting and elaborating the information by the open data of the city of Turin

```python
import pandas as pd
import math
import matplotlib.pyplot as plt
```

Uploading the file: This portion of the code loads the csv file that contains the information on business activities. The second line specifies the fields in the table that are kept and are useful for the calculations to be performed. The other fields in the file were not useful for the purpose of the project. The result is shown in the table below the code.

```python
df = pd.read_csv('attivita_commerciali.csv', encoding='latin-1', lineterminator='\n', delimiter=';')
df = df.loc[:, ['INDIRIZZ', 'TIPO_MER', 'DESC_RIP', 'DETT_RIP', 'CAT_MER', 'CAP']]
df.head()
```

	INDIRIZZ	TIPO_MER	DESC_RIP	DETT_RIP	CAT_MER	CAP
0	VIA PIETRO PALMIERI 61/A	.	Somministrazione	D	Nessuna	10138.0
1	VIA PASQUALE PAOLI 9	.	Acconciatori/estetisti	Acconciatori	Nessuna	10134.0
2	VIA PASQUALE PAOLI 9	EXTRALIMENTARI	PICCOLE STRUTTURE	Vend.dettaglio con superf. fino a mq 250	Bigiotteria	10134.0
3	VIA PASQUALE PAOLI 26/A	.	Somministrazione	B	Nessuna	10134.0
4	VIA PASQUALE PAOLI 33/A	EXTRALIMENTARI	PICCOLE STRUTTURE	Vend.dettaglio con superf. fino a mq 250	Serramenti	10134.0

Filter Table: In this portion of the code it is possible to filter the initial table on a specific city area. We can focus on a portion of a street, defined by a range, or on an area defined by a certain zip code.

Search_address:

Input:

String min_integer -> interior here the considered street section begins
String max_integer -> interior in here the considered street segment ends
String address -> name of considered life e.g. street/course name
DataFrame table -> table of business activities
Output: table with activities between [address + min_integer, address + max_integer]

search_CAP (zip code)

Input:

Int postal_office_code -> zip code that you want to consider in the search
DataFrame table -> table of business activities

Output: table with the business activities that have postal_code == zip_code

```python
# Definire qui i valori per la ricerca che si vogliono usare
indirizzo = 'corso sebastopoli'
min_interno = '214'
max_interno = '243'
cap = '10136'

filtered_df, used_cap = search_address(min_interno, max_interno, indirizzo, df)        # search_CAP(cap, df)
filtered_df.head()
```

	INDIRIZZ	TIPO_MER	DESC_RIP	DETT_RIP
9129	CORSO SEBASTOPOLI 214/A	ALIMENTARI	FORME SPECIALI DI VENDITA	Vend.dettaglio a mezzo apparecchi autom.
9130	CORSO SEBASTOPOLI 214/A	MISTA	PICCOLE STRUTTURE	Vend.dettaglio con superf. fino a mq 250
9131	CORSO SEBASTOPOLI 214/A	MISTA	PICCOLE STRUTTURE	Vend.dettaglio con superf. fino a mq 250
9132	CORSO SEBASTOPOLI 214/A	MISTA	PICCOLE STRUTTURE	Vend.dettaglio con superf. fino a mq 250
9133	CORSO SEBASTOPOLI 216/A	MISTA	PICCOLE STRUTTURE	Vend.dettaglio con superf. fino a mq 250

Histogram: we can print an histogram that shows for each business category how many stores are in the chosen area.

df_cat_mer -> Dataframe where we have for each category the total number of occurrences found in the table filtered above
tot_shop -> I count how many businesses there are in total.

```python
# Dataframe dove ho per ogni categoria il numero totale di occorrenze trovate
df_cat_mer = pd.DataFrame(filtered_df['CAT_MER'].value_counts()).reset_index()
df_cat_mer.columns = ['CAT_MER', 'count']
# Conto quante attività commerciali ci sono in totale
tot_shops = df_cat_mer['count'].sum()

print("Numero attività commerciali: ", tot_shops)
print("Numero di categorie: ", len(df_cat_mer.index))

df_cat_mer.plot(kind='barh', figsize=(8, 10))
if used_cap:
    plt.ylabel('CAP: ' + str(df['CAP'].iloc[0]))
else:
    plt.ylabel(indirizzo + ' ' + min_interno + ' - ' + max_interno)
plt.xlabel('Numero di attività')
plt.title('Numero di attività per ogni categoria')
plt.show()
```

```
Numero attività commerciali:  18
Numero di categorie:  10
```

The code can calculate the diversity of activities for the street.

Urban diversity: A function that calculates the urban diversity index related to the specific equation is defined. It adds the probability of occurrence and information values to the filtered table for each row.

urban_diversity

Input:

Dataframe table -> filtered table of categories and the number of stores belonging to them
Int val -> number of total businesses

Output: bit/person information value and updated table with two new columns: one for probability of occurrence and one for information

urban_diversity_score

Input:

Int ud_index -> bit/person index value
Output: urban_diversity_score

```python
def urban_diversity(table, val):
    table['p'] = table['count'].apply(lambda x: round(x / val, 6))
    table['H'] = table['p'].apply(lambda x: round(x*math.log(x), 6))
    return round(-table['H'].sum(), 4), table

def urban_diversity_score(ud_index):
    if urban_diversity_index <= 1 :
        return 1
    elif 1 < ud_index <= 1.9:
        return 2
    elif 2 < ud_index <= 2.9:
        return 3
    elif 3 < ud_index <= 3.4:
        return 4
    else:
        return 5
```

```python
urban_diversity_index, df_ud = urban_diversity(df_cat_mer, tot_shops)
print("Diversità urbana: ", urban_diversity_index)
print('Punteggio: ', urban_diversity_score(urban_diversity_index))
```

```
Diversità urbana:  2.0582
Punteggio:  3
```

Hence, we can have the Urban diversity index (2.0582) and the score (3) for the selected test area, collecting all the activities that can be then displayed as aggregated per area (Figure 7).

```python
df_ud
```

	CAT_MER	count	p	H
0	Extralimentari	5	0.277778	-0.355815
1	Alimentari	4	0.222222	-0.334239
2	Mobili	2	0.111111	-0.244136
3	Tabacchi	1	0.055556	-0.160577
4	Gastronomia	1	0.055556	-0.160577
5	Supermercato	1	0.055556	-0.160577
6	Autoveicoli e motoveicoli	1	0.055556	-0.160577
7	Vendita al dettaglio di cose antiche ed usate	1	0.055556	-0.160577
8	Tessuti	1	0.055556	-0.160577
9	Macelleria	1	0.055556	-0.160577

Save the last table to a csv file

```python
if used_cap:
    indirizzo_completo = f'{cap}'
else:
    indirizzo_completo = f'{indirizzo}_{min_interno}-{max_interno}'
df_cat_mer.to_csv('cat_mer_{}.csv'.format(indirizzo_completo), sep=';', encoding='latin-1', index=True)
```

The last code command allows the use of the information to create a table to be exported or it is possbile to plot the histogram of the activities used to calculate the index (Figure 7).

Possible future development of this approach has been suggested as follows:

- Adapt the code to calculate the remaining indices (thermal and acoustic, air quality, urban livability index, and morphological indices);
- Dashboard creation for greater accessibility of data;
- Ability to expand the system to other cities.

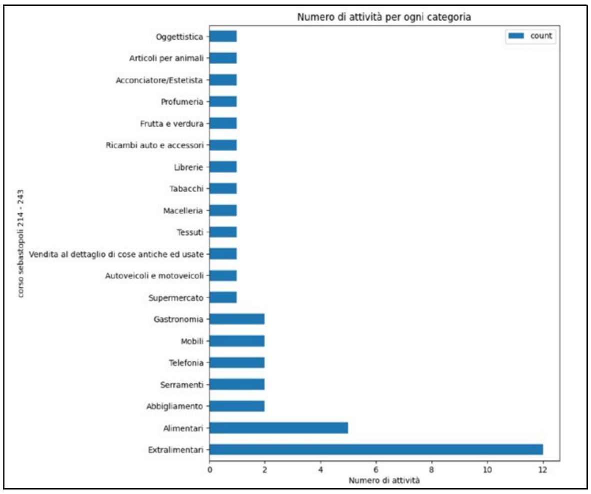

Figure 7: Number of activities per each category for a test zip code (10136).

3. THE DEVELOPMENT OF A SHARED APPROACH

Based on the conducted analyses, it is conceivable that a collaborative pathway among students from different degree programs would be highly beneficial regarding knowledge increase and cultural and language cross-fertilization. This could promote co-creation and interdisciplinary cooperation, enhancing students' possibilities and capabilities. It could also initiate a fresh collaborative approach concerning the sustainability of urban spaces on a novel basis [8]. The first aspect of systematizing to continue an effective transdisciplinary collaboration is related to the case study. Precisely, because of the need to "calibrate" the method and develop an approach that is useful to both groups, in the next step, we should work on the same case study, allowing the teams to interact and tune the calculation and design solutions according to the possibility of performing several iterations, in the early stages of the site investigation. A second relevant aspect is to enable students of Architecture, who are not prepared to develop ad hoc tools for the evaluation of specific parameters to have access to simplified calculation and simulation systems, allowing for quick verifications during the design process to enable more appropriate and informed design choices.

4. CONCLUSION

The paper delineates a dual experience carried out across two distinct universities and academic programs. However, this experience should ideally continue, as the genuine effectiveness becomes evident when these tools are put into practical use, tested, adjusted, and adapted to real-world cases, specifically when applied to the architectural design of an urban space. It is intriguing to consider that this process was initiated by the designer's requirement, then evaluated and observed from the different perspective of a computer scientist. Ultimately, through a transdisciplinary approach, it can return to the realm of design, where the product is "tested" and contributes to its refinement.

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