Abstract: By employing overly simple rules for mimicking driving behavior in urban traffic, it can be seen a synergistic effect between motorists and motorcyclists in an agent-based environment. When motorcyclists ride in between the available space of stopped or slow-moving vehicles, motorists are forced to reduce their lane-changing maneuvers without affecting their speed, but the resulting mixed traffic proved to be increased. Further suggestions on the possible ways to study and apply these synergistic effects in the real world are presented.

Looking for the synergy of road-users in urban traffic

Recent evidences show some reasons that explain why inhabitants of highly-dense cities prefer the use of “risky” means of transportation (motorcycles) instead of “safe” vehicles [1]. Economic factors such as the low-prices for acquiring and maintaining a motorcycle are obvious advantages. Yet, other non-trivial factors appear to be relevant
for road-users who confront urban traffic congestions on a daily basis. The practice of “motorcycle lane-sharing” occurs when motorcyclists ride in between the lanes of stopped or slow-moving vehicles, despite the fact that this practice might jeopardize traffic safety on the roads. This practice of mobilization, induced by vehicular density and economic factors, presents us a behavioral interaction between motorists and motorcyclists who act as elementary components of a phenomenon which has its own peculiarities at both the macroscopic and the microscopic scale.

The initial approaches of traffic provided us a set of tools to analyze the relationship between its macroscopic variables (i.e., speed, flux and density) to deal with traffic management issues. However, other complementary approaches have been developed to offer us a viewpoint which enables us to understand why road capacity can be benefited from the synergistic effects of motorcycle lane-sharing. These approaches are intended to understand the dynamics of traffic from the behavioral interaction that takes place when motorists share their lane with motorcyclists [2].

It has been noticed, for instance, that the speed of motorcyclists is systematically higher than the speed of motorists and their maximum flow rates and critical speeds decline with an increase of maximum speed deviations [3]. It has also been observed that the presence of motorcycles enlarged the capacity of the road, due to the fact that motorcyclists are able to progress by filtering when the movements of cars are constrained by vehicular density. This behavior, however, can be affected as the number of motorcycles increase; so the introduction of more motorcycles will inevitably impair the cars’ movement, producing a lower traffic flow in certain conditions [4].

The complexity of traffic and the intrinsic relationships between its macroscopic and microscopic properties can be hard to tackle in natural settings due to the amount of instrumentation that is required for data gathering purposes. Fortunately, nowadays we have several tools that can be applied to overcome some of these difficulties. Computerized simulations in general and agent-based simulations in particular are just a couple of these tools especially suited to study urban traffic as a complex system [5]. But,
how can we observe the synergy in urban traffic by using these tools? What are the variables that we need to collect and analyze in order to detect such synergy?

The elements of synergy in urban traffic

Synergy, roughly understood as the creation of a whole that is greater than the simple sum of its parts, is a ubiquitous phenomenon which has been observed in several fields like particle physics, chemistry, genetics, ethology and psychology, just to mention but a few [6]. In urban traffic, however, it appears to be a subtle phenomenon closely related to the aforementioned practice of motorcycle lane-sharing. As part of my doctoral thesis [1], I designed an agent-based simulation to examine the quantitative effects of motorcycle lane-sharing on motorists’ behavior in terms of their average speed and the frequency of acceleration/deceleration and lane-changing maneuvers. The simulation experiment consisted in comparing these metrics with and without the presence of motorcyclists on a virtual double-lane road created in a multi-agent simulation platform. In the simulation, motorcyclists choose a lane to share, they never attempt to change their chosen lane and drive in it at a speed which is higher than those of the motorists. The simulations showed that under these specific circumstances the motorists get almost confined to their lane, and were forced to increase up to four times their acceleration/deceleration maneuvers without significantly affecting their average speed. These results, although very specific for motorists, say little about the synergy in urban traffic. But the view of the whole system changes when the analysis focuses on examining what happens with the simultaneous mixed traffic of motorists and motorcyclists; also known as “heterogeneous traffic”.

Heterogeneous traffic flow as an indicator of synergy

The heterogeneous traffic is characterized by the interaction of motorcycles and four-wheeled vehicles driving without lane discipline. The absence of lane discipline consists in the vehicular movement that is influenced by the presence of vehicles in the front as well as on the sides. This led to a complex traffic behavior and it cannot be
analyzed by using conventional traffic variables such as time headway and space headway (i.e., the “bumper-to-bumper” distance that separates two vehicles). Consequently, it is desirable to have a metric that can represent the heterogeneous nature of traffic. Since varying vehicle dimensions are attributed to the lack of lane discipline, a modified measure of occupancy known as “area occupancy” has been recently proposed [7].

Area occupancy is based on the concept of “occupancy” which is defined as the percentage time any arbitrary road section is occupied by a vehicle over a given period of time. The calculus of area occupancy is as follows:

$$\rho_A = \frac{\sum_{i=1}^{N} O_i \times w_i \times d}{T \times W \times d}$$  \hspace{1cm} (1)

Where $$\rho_A$$ is area occupancy; $$O_i$$ is occupancy time of the $$i^{th}$$ vehicle in seconds; $$w_i$$ is the width of the $$i^{th}$$ vehicle; $$W$$ is road width; $$d$$ is the length of the road section under consideration; and $$T$$ is the observed time period in seconds. In equation (1), the numerator value takes care of the occupancy time (similar to occupancy); the amount of time a vehicle with a given area is spending on the road section under observation. Its value will depend on the traffic composition and speeds of the vehicles. It must be noticed that the practice of motorcycle lane-sharing allows the motorcyclists to have a faster occupancy time due to the possibility of percolating through stopped or slow-moving vehicles. Thus, the purpose of measuring heterogeneous traffic flow presents us an interesting opportunity to examine the synergy that takes place in urban traffic when motorists and motorcyclists interact on the road.

Some years ago Indian researchers tried to estimate the heterogeneous traffic flow by using a sophisticated video analysis software to collect traffic volumes and composition by automatically identifying types of vehicles on the road [8]. They collected the data on the National Highway – 1 (NH-1), connecting New Delhi and Amritsar. In this setting, they employed two reference lines to take the records of the time instances at which the vehicles were entering and leaving the road section. By
considering these data and length of the road section, the speeds and occupancy times were calculated for all the vehicles during a period of 30 minutes. Their results showed minimum fluctuations of speed. Yet, the interesting part of their results was associated with the observed differences between the occupancy and the area occupancy. It turns out that apart from speed, $\rho$ depends on the vehicle length and $\rho_A$ depends on the vehicle area. When more short vehicles with low vehicle area or vehicles with large areas were traveling on the roads, it was observed some differences between the values of $\rho$ and $\rho_A$ in some moments of the observation period. These differences can be observed from Figure 1 which shows the fluctuations of $\rho$ and $\rho_A$ over the observed period.

![Variations of occupancy and area occupancy over time](image.png)

*Figure 1 Variations of occupancy and area occupancy over time*

In Figure 1 the abscissa shows us every minute of observation. The left part of this figure shows the time variation of occupancy $(\rho)$, while the right part shows area occupancy $(\rho_A)$ for the same traffic flow. Since $\rho_A$ is encompassing area of the vehicle and its speed under prevailing traffic conditions, its value is different from that of $\rho$.

The study of area occupancy gives an insight into the behavior of heterogeneous traffic. The results obtained from this study have major ramifications on concepts of roadway capacity and level of service under real heterogeneous traffic conditions. The concept of area occupancy can also be used as a measure of performance in converting heterogeneous traffic stream into an equivalent homogeneous traffic stream, which is easily analyzed by observing the fundamental diagrams that depict the relationship among speed, flow and density. However, this measure needs further validation under
various traffic regimes (i.e., free-flow, congested, etc.). Since vehicle dimensions are very crucial in realizing the area occupancy, there is a lot of work to be done in this direction.

Another remarkable effort was done by Lee [9] when he compared the effects of traffic composition on the overall traffic. As part of his doctoral thesis he developed an agent-based model to simulate the heterogeneous traffic with different proportions of motorcycles on a virtual road of 300 m long and 10 m wide with three lanes in one single direction. In particular, his study compared the density-flow relationship in five different scenarios which are summarized in Figure 2.

![Figure 2 The density-flow relationship under different traffic compositions](image)

As can be seen from Figure 2, the worst traffic corresponded to a 100% passenger car flow, while the best one corresponded to the scenario of 100% motorcycles and the different compositions occupied an intermediate position between these two “homogeneous traffics”. These results are consistent with those that indicate the benefits of splitting the heterogeneous traffic by creating a dedicated motorcycle lane [9]. Clearly
then, the interaction between motorists and motorcyclists produce a traffic flow synergy that can be exploited in natural settings.

**Final comments**

In this paper I summarized the experimental results of three different studies that show the possibilities to observe and model the heterogeneous traffic and the synergy that takes place on the road when motorcyclists and motorists interact. This synergy consists in the rise of the road capacity and the overall traffic flow, due to the fact that the motorcycle can exploit the road space by filtering through a slow moving flow using the clearance between two parallel cars or the possibility to weave in and out of a stationary flow via the safety margins between vehicles.

The aforementioned results required a considerable amount of work to model the behavior of the heterogeneous traffic and its corresponding validation with field observations. These incipient efforts were intended to observe, analyze and simulate some complexities of the heterogeneous traffic that still require further studies to eventually improve the way we deal with real traffic management.

In computer simulations we have seen that the overall traffic flow improves when the traffic composition is not completely homogeneous. Thus, a fruitful exploration in the near future should take into account when is convenient (for the whole traffic system) to restrict the practice of motorcycle lane-sharing. Another fertile venue in studying the synergy of motorists and motorcyclists is to examine under what specific conditions works this synergy; namely, to examine the effects of lane-width, number of lanes, etc.).
References


