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Fast-food drive-throughs in developing countries

A modern convenience perpetuating unsustainable transport decisions?

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Abstract: Fast-food drive-throughs are a common feature in our fast-paced lives where convenience and service access are highly prized. This convenience comes at a high environmental price: long queues of idling vehicles guzzle fuel and generate emissions linked to global warming and health concerns. Drive-throughs also generate significant income for franchisees and reduce parking requirements at fast-food outlets. Fast-food and drive-throughs are becoming more prevalent in the developing world at a time when these countries are facing rapidly increasing traffic congestion, driven by a desire for private transport use. This study considers aspects of sustainability of drive-throughs according to the mobility paradigm in the developing world, where vehicle-centric urban form and rapid development are contributing to a mobility crisis. The drive-through is a prime example of capitalist vehicle-centric urban form. This paper is intended as a starting point for discussion on drive-through appropriateness in developing countries. Only two aspects of drive-through operations are considered in this initial investigation: the cost of using a drive-through (fuel cost and environmental cost, approximated by the emissions load), and the space saving benefit realized by eliminating parking. This research found that drive-throughs save substantial land area by reducing parking and stimulate higher profits, making it unlikely that drive-throughs will be phased out, even with the significant environmental impact of drive-throughs quantified in this paper. Recommendations for improved operations of drive-throughs are therefore suggested to mitigate long idling times in drive-through queues, and a call for more sustainable land-use planning is proposed.

1. INTRODUCTION

Traffic congestion in the developing world is increasing rapidly, driven by steadily increasing private transport use (Sperling & Clausen, 2002; Bashingi, Mostafa, & Das, 2020) that is linked to economic growth and urbanization occurring particularly quickly in developing countries (Rehana Shrestha et al., 2013). The increased use of private vehicles is also escalating energy consumption and carbon emissions in developing countries (Mittal & Biswas, 2019).

Firmly held models that explain increasing car ownership in the developing world view the car as a status symbol (the psychological model) which is purchased according to the unbiased choices of consumers (the

economic model) (A.Vasconcellos, 1997). According to these models, cars are desirable because they convey social standing and success and are purchased because of "want" not "need". Vasconcellos (A.Vasconcellos, 1997) argues that these models are flawed, particularly for the developing country context, and proposed an alternative "sociological" model to describe private vehicle demand. In the sociological model, potential car owners consider the car an essential contributor to daily tasks, making the decision to own and use a private car a function of utility rather than status. This perception of the car as an essential tool is reinforced by two aspects particular to developing countries: firstly the lack of alternative public transport options that are competitive in both efficiency and convenience to cover the vast distances typically travelled in developing country cities; and secondly, urban and transport policies, resulting from capitalist modernization pressure, that have shaped urban space promoting private vehicle use over public transport (Mittal & Biswas, 2019) (A.Vasconcellos, 1997). According to this model, urban form can perpetuate or mitigate dependence on private vehicles by the growing middle-class in developing countries. This notion that urban form can influence travel behavior is supported by extensive research (Chen & Felkner, 2020).

The fast-food drive-through is a prime example of urban form that perpetuates the sociological model of the car as the only means of providing adequate mobility. Fast-food restaurants and their drive-through facilities are becoming ever more prevalent in the developing world (Prasetyo et al., 2021), boosted by fast-food popularity and the modern appetite for convenience and quick service. Drive-through facilities offer patrons the option of remaining in their vehicles while ordering take-away food instead of parking and entering a fast-food restaurant. Drive-throughs therefore decrease space requirements at fast-food restaurants by reducing parking demand; however, drive-throughs also result in lengthy queues of idling vehicles consuming fuel and pumping out emissions.

The purpose of this paper is to stimulate long overdue discussion among urban planners in developing countries around the question: are fast-food drive-throughs in their current form sustainable and appropriate in the developing country context? Literature indicates the need to encourage development, while simultaneously reducing carbon emissions and energy use, particularly in the developing country context, where issues of climate change are overlooked in preference of development (Rehana Shrestha et al., 2013).

The authors of this paper are not aware of studies that consider the appropriateness of drive-throughs according to the mobility paradigm in the developing world. Research relating to drive-through impacts are all USA-based, and only considered the negative impacts of excess fuel use and emissions generated when using drive-throughs (Hill et al., 2016; Mattingly et al., 2009; Baxter & Stafford, 1985). Studies to improve movement through drive-throughs, with the goal of reducing waiting time (and therefore reducing emissions), do so from a developed country context (Whiting & Weckman, 2004; MarkDougherty, 1997). Studies conducted in developing countries related to fast-food drive-through facilities are limited to studies on trip generation (Al-Madadhah & Imam, 2020; Ahmed et al., 2014), and considerations of directing food selection from menus (Prasetyo et al., 2021).

This paper is intended to serve as a starting point for important discussion on drive-through appropriateness. Only two aspects of a drive-through are considered in this initial investigation: the cost of using a drive-through (both the personal fuel cost and the environmental cost which is

approximated by the emissions load), and the space saving benefit realized by eliminating parking need. These aspects are the most obvious points of contention in the arguments for the existence or suppression of fast-food drive-throughs. This study is unique in considering the space saving aspects of drive-throughs that reduce the parking requirements. This paper also brings together various alternative design strategies that maintain the function of the drive-through, while still decreasing the emissions load generated at typical drive-throughs. The paper therefore tries to bring a balanced approach to the discussion of fast-food drive-throughs in a developing country context.

2. LITERATURE REVIEW

2.1 Vehicle-centricity of drive-throughs

Many fast-food franchises are designed to accommodate access by private vehicles, as "roadside drive-in and drive-through facilities" (Freund & Martin, 2008). Parking and access roads surrounding these facilities often limit access to "walk-in" (and therefore public transport using) patrons, encouraging private vehicle use. Drive-throughs typically have one-way traffic flow around the outer edge of the restaurant building, with service windows for ordering, payment, and collection of food, in this order. The number of circulating lanes and number of service windows may differ depending on the franchise and the site. In some instances, ordering is done through a speaker system, or the ordering and payment points are grouped, or the payment and collection window may be combined (Hill et al., 2016).

A study conducted in 2006 in the USA found that 57% of people choose to use a drive-through facility rather than park and enter a restaurant (Christina A Roberto et al., 2010). The drive-through configuration, linked with production line type operations, maximizes customer turnover and reduces patron waiting time, increasing profits. Approximately 60% of the revenue of a fast-food restaurant is generated by the drive-through (Hill et al., 2016). Fast-food restaurants with drive-through facilities generate approximately 40% higher revenues than those without (Wet, 2018).

The popularity of drive-through facilities is related to the convenience offered to customers of quick transactions (many fast-food restaurants prioritize drive-through patrons), no need to find a parking space, and not having to stand in a queue (Baxter & Stafford, 1985). Additionally, drive-throughs could be more economical for franchisees because building and parking area sizes can be reduced if patrons never park and enter the restaurant (Baxter & Stafford, 1985). People with a physical disability and parents with small children do not need to get out of their cars, another benefit of drive-throughs (MarkDougherty, 1997).

Fast-food restaurants have a higher customer turnover rate than sit-down restaurants, therefore increasing the trip generation of these facilities (Stander et al., 1989). Trip generation rates for fast-food restaurants around the world vary according to the individual country. The South African recommended trip generation rate for a fast-food restaurant is 20 vehicle trips per 100 m2 of Gross Leasable Area (GLA) in the peak hour, and 200 trips per 100 m2 GLA per day (Committee of Transport Officials, 2013). A Malaysian study estimated trip generation of fast-food restaurants to be 21.04 trips per 100 m2 GLA during weekday evenings, and 24.56 trips per

100 m2 GLA for weekend evening peaks (Ahmed et al., 2014). The Institute of Transportation Engineers in the United States suggests a trip generation rate of 42.87 trips per 100 m2 (converted from 38.9 trips per 1000 ft2) in their 2003 Trip Generation Manual, while the suggested rate in Abu Dhabi is 19.53 trips per 100 m2 during the weekday evening peak hour (Al-Madadhah & Imam, 2020).

2.2 Emissions and fuel consumption at drive-throughs

Vehicle emissions and fuel consumption at drive-throughs is directly impacted by the time that vehicles spend in the drive-through and the movement of vehicles while queuing. Time spent queueing is influenced by the number of vehicles in the queue and the efficiency with which food orders are processed. The design of a drive-through facility in terms of number of lanes and service windows impacts time spent idling (Hill et al., 2016). Emissions were found to increase with more service points and one lane configurations performed better than two lane configurations.

The progression of the queue at a drive-through is slow and continuous, with each customer receiving service one at a time, resulting in a stop-start movement pattern (MarkDougherty, 1997). Drivers are typically observed to keep their vehicle engines running during this queued time. Service of the queue at a drive-through is classified as first-in-first-out. The main modes of vehicle movement at drive-throughs were predictably found to be idling, low speed coasting and low-powered acceleration (Hill et al., 2016). Each of these movement modes are associated with different fuel usage and emissions outputs. Slow stop-start movement of vehicles is one of the worst operational conditions in terms of fuel usage and pollution generation (MarkDougherty, 1997).

Dougherty (1997) estimated that a single fast-food drive-through facility with an average service time of 3 minutes per customer and 2000 vehicles per week, could result in the consumption of 780 liters of fuel per year more than would be used if the vehicles had been parked. Mattingly, et al. (2009) estimated that closing a drive-through would reduce emissions of Nitrogen Oxides (NOx) by between 60 and 70% in the vicinity of the drive-through.

Vehicle emissions include Carbon Dioxide (CO2), water vapor and Nitrogen Oxides (NOx), which together with surface-level ozone and methane, are five of the most damaging greenhouse gases (Rafferty, 2018). These gasses accumulate in the atmosphere, trapping solar radiation thereby increasing global average temperatures and contributing to climate change.

In addition to the environmental impact, gases found in vehicle emissions have been linked to significant health risks. Vehicle emissions include Hydrocarbons (HC), which increase the risk of cancer in individuals with prolonged exposure (Barnett, 2012), and Carbon Monoxide (CO) which reduces the amount of oxygen that red blood cells can carry, leading to an increased risk of heart attack. Heart related medical problems were identified as the main contributor towards pollution related fatalities (He & Qiu, 2016). A 2002 study that exposed pregnant mice to exhaust emissions, found the mice pups to be affected by low birth weight and were physiologically immature at birth (Krzyżanowski, Kuna-Dibbert, & Schneider, 2005). Pollutants from vehicle emissions also negatively affect male fertility, with sperm motility affected by Nitrogen Oxide (NO) (Michele De Rosa et al., 2003).

The health impact of vehicle emissions on humans is related to pollutant exposure. Urban spaces predominantly enclosed by buildings (the environment of many fast-food drive-throughs) are often more polluted due to vehicle emissions not dispersing easily. This means that staff that work at drive-throughs are more likely to be exposed to high levels of emissions for extended periods of time (Barnett, 2012).

Consideration of the environmental impact of drive-throughs has been gaining traction over the past few years. Various cities across the USA have banned the construction of new drive-throughs in an effort to reduce pollution (Charlton, 2019; Wida, 2019). A recent Canadian study detailed several Canadian municipalities implementing by-laws to ban fast-food drive-through facilities (Nykiforuk et al., 2018). These bans have received mostly negative feedback from people, with one poll determining that 69% of the respondents (of just over 500 participants) were contemptuous of the ban (Wida, 2019), with many indicating skepticism that the ban will bring desired environmental improvements, while also indicating that they do not wish to lose the convenience associated with a drive-through.

2.3 Alternative drive-through configurations

Two operational changes have been identified in literature that could decrease the environmental impact of drive-throughs, while allowing patrons to stay in their vehicles, maintaining the quick service and convenience of the drive-through. These include the "passive and active queuing system" and the "parking slots" system.

2.3.1 Passive and active queueing systems

Significant fuel savings and emissions reduction may be realized if drivers can be convinced to turn off their vehicles' engines when waiting in queue at a drive-though. According to Rahman, et al. (Rahman et al., 2013), the amount of fuel used by a diesel vehicle when idling for 10 seconds warrants the engine being turned off. A time of between 6 and 10 seconds is applicable to petrol engines.

The USA Federal Highway Administration has recommended that vehicles are turned off while queuing at drive-throughs (Hill et al., 2016), however vehicles are predominantly left idling. The primary concern for drivers when asked to "switch-off" their engines is the anticipation that the vehicle in front will imminently move forward and the disquiet that drivers behind will grow frustrated if they do not move forward in the queue immediately (Schau & Gilly, 1998). This anxiety can be addressed by dividing a drive-through zone into passive and active sections, as suggested by Dougherty (1997) in his research on block queueing. The passive and active sections of the queue are divided by a traffic signal. Vehicles upstream of the signal (passive queue) must be turned off until the traffic signal allows a certain number of vehicles to progress to the active queue where vehicles are permitted to idle while they order, pay, and collect food. Instead of idling and inching forward into any gap, cars remain off until they are permitted by the signal to move forward by three car lengths.

2.3.2 Parking slots

Whiting and Weckman (2004) studied operational efficiencies at various configurations of drive-through facilities, considering the waiting time of patrons as a measure of efficiency. The study compared the traditional drive-through layout (vehicles progress from order point to pay point to collection window in a first-in first-out queue) to a "parking slots" option where drivers place their order and pay as per usual drive-through protocol, and then park and wait for their order to be delivered to their vehicle by restaurant staff.

Whiting and Weckman (2004) found that the "parking slots" system marginally improved average waiting time for each vehicle but found a significant reduction in the maximum "Time in System" of individual vehicles during peak service periods. This is because drive-through users with a relatively simple order do not need to wait for a vehicle in front that may have a substantial order requiring long preparation time. A maximum of four parking spaces was found to be necessary to handle any arrival rate at the drive-through. During periods of low volume, the slots do not need to be used and vehicles can collect their order at the traditional collection window.

The Whiting and Weckman (2004) study considered convenience for patrons but did not consider emissions reductions. However, the impact of reducing "Time in System" on the sustainability of a drive-through is obvious. The bottleneck of any fast-food drive-through is the delivery window. The "parking slots" essentially removes this bottleneck by restructuring the queuing system from "first-in-first-out", to a system where the order with the lowest complexity can be handled first. Additionally, parking in a slot is likely to naturally encourage drivers to turn off their vehicles while waiting for their order, therefore also gaining benefits of reducing engine idling time.

Limited additional space is required to retrofit existing drive-throughs according to the "parking slots" system if there is space for at least two parking bays to be incorporated (Whiting & Weckman, 2004). This can be done with minimal impact to the building, circulating lanes and operations.

3. METHODOLOGY

3.1 Research Approach

The aim of this paper is to start a conversation on the appropriateness of fast-food drive-throughs in developing countries. Drive-throughs are a typical example of urban design that encourages private vehicle usage. Urban planners in developing countries should discourage urban form that is openly aimed towards private car travel, as this, together with a lack of competitive public transport options, drive rapid increase in private vehicle use by the steadily growing middle-class in developing countries (A.Vasconcellos, 1997).

Vasconcellos (1997) noted that the only aspect likely to have any impact on the desire of the people to own and use private cars would be awareness of environmental issues, such as increased emissions that are associated with high private vehicle usage. Additionally, the actual cost of fuel may also be a likely deterrent in the use of cars by the working middle-class. This paper therefore specifically considers fuel usage and emissions associated with drive-through use.

From the capitalist point of view of fast-food franchisees and property developers, it makes financial sense to have the smallest possible erf and limit the use of potential Gross Leasable Area (GLA) by non-revenue generating parking. This paper therefore also considers the space saving aspects of a drive through on parking, which has not been quantified before.

Fuel use and emissions generated at drive-throughs have not been quantified in a developing country, only in the USA. The trip generation potential of fast-food establishments was confirmed to be different between developing countries and the USA in Chapter 2.1, highlighting the need for a study of fuel use and emissions in a developing country. Investigation of drive-through operations was carried out at two fast-food restaurants with drive-through facilities in South Africa, a developing country, to allow emissions, fuel usage and parking load of drive-throughs in a developing country to be considered.

3.2 Study Area

Two fast-food restaurants in Stellenbosch, South Africa were studied: a KFC and McDonald's. The restaurants are identified as Restaurant 1 (R1) and Restaurant 2 (R2) (in no particular order) to protect the anonymity of the restaurants that were studied (in line with the institutional permission obtained from each restaurant to participate in this study).

The layout of the restaurants' parking areas and drive-throughs are presented in *Figure 1*, indicating vehicle movement through the area. Both restaurants are in the forecourt of filling stations adjacent to convenience shops. Parking at R1 is shared with the adjacent convenience shop due to their proximity. A total of 19 parking spaces are available for both facilities. R2 is located further away from the filling station and convenience shop with which it shares a site and essentially has exclusive use of the eight parking spaces located directly in front of the restaurant.

Figure 1. Layout of drive-through and parking area of R1 (left) and R2 (right)

3.3 Drive-through study

Operations at the fast-food restaurants were observed between 12:00 and 14:00, the peak service period of the drive-throughs according to restaurant management. Data was collected during October 2019, with care taken to

exclude holiday periods, which may impact the number of patrons visiting the restaurants because Stellenbosch is a university town where traffic volumes are known to drop severely during holiday periods.

A partial number plate and the time that each vehicle entered and exited the drive-through was noted, allowing the number of vehicles and the time that each vehicle spent in the drive-through to be determined. The anonymity of drive-through patrons was ensured by observing partial number plates.

The emissions load and fuel use at the two drive-throughs were calculated according to standard fuel and emissions rates for petrol vehicles. For brevity, vehicle emissions are estimated assuming that all vehicles using the drive-throughs are standard petrol engine passenger vehicles.

3.4 Parking study

A parking study was done at both R1 and R2 to determine parking utilization, duration, and turnover. The parking study was conducted during the same two-hour period as the drive-through facility observation. Vehicles in the parking area were surveyed every 15 minutes. The entire parking area available for R1 and the nearby convenience store (19 parking spaces) was observed because no distinction between vehicles using either facility could be made. The eight parking spaces in front of R2 were observed. The last three digits of the number plate of vehicles occupying parking spaces was noted to maintain anonymity. Various information could be determined from this parking study, including parking accumulation (number of vehicles parked at any point in time), parking turnover (number of vehicles using a single parking space for the study period) and parking duration (average time that each vehicle is parked for) (Garber & Hoel, 2014).

4. DATA COLLECTION

4.1 Drive-through operations

Data was collected at the two drive-throughs during the peak service period (12:00 to 14:00). During this period, 102 and 83 vehicles entered the drive-throughs of R1 and R2 respectively. Figure 2 summarizes vehicle arrivals at the drive-throughs in 15-minute intervals. Arrivals at both R1 and R2 peaked between 13:00 and 13:15. The average time that vehicles spent in the drive-throughs was 3 minutes, 36 seconds at R1 and 4 minutes, 13 seconds at R2. The longest time that a vehicle was observed to spend in the drive-throughs was 7 minutes, 13 seconds (R1) and 9 minutes, 11 seconds (R2), while the shortest times were 51 seconds and 56 seconds respectively. These service times are similar to those found at a drive-through in the USA: average time in drive-through of 4 minutes, 58 seconds, and minimum and maximum observed times of 1 minutes, 13 seconds and 12 minutes, 2 seconds respectively (Whiting & Weckman, 2004).

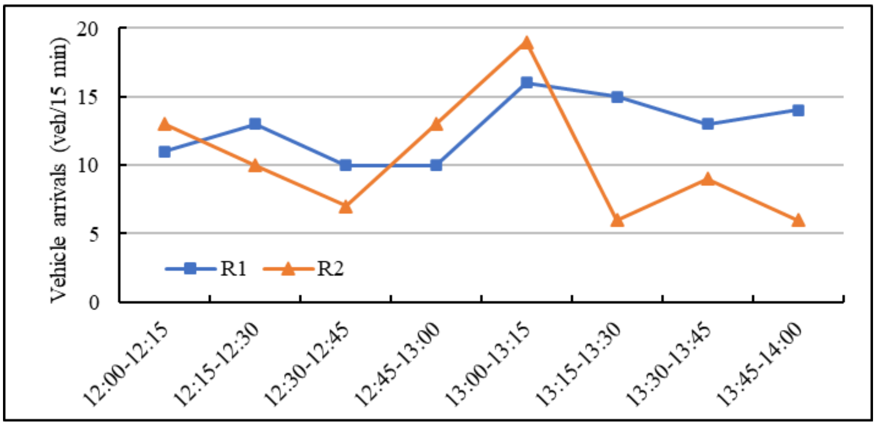

Figure 1. Vehicle arrivals at drive-throughs

4.2 Parking study

The parking accumulation at R1 and R2 is presented in *Figure 3*, representing the number of parking spaces occupied each 15 minutes. Neither parking area reached capacity (dashed lines) during the study period, implying that all drivers who wanted to park and enter the restaurants were able to find a parking space during the peak operational hours. This indicates that patrons using the drive-through did so because of choice, not unavailable parking.

A total of 95 vehicles parked in the 19 parking spaces at R1 in the 2 hours observed (32 vehicles at R2 in the 8 available spaces), representing parking volume. *Table 1* summarizes the parking study results, including parking turnover and duration. Parking spaces were more frequently used at R1 than at R2, according to the higher turnover. Vehicles also parked for slightly longer at R1 than at R2.

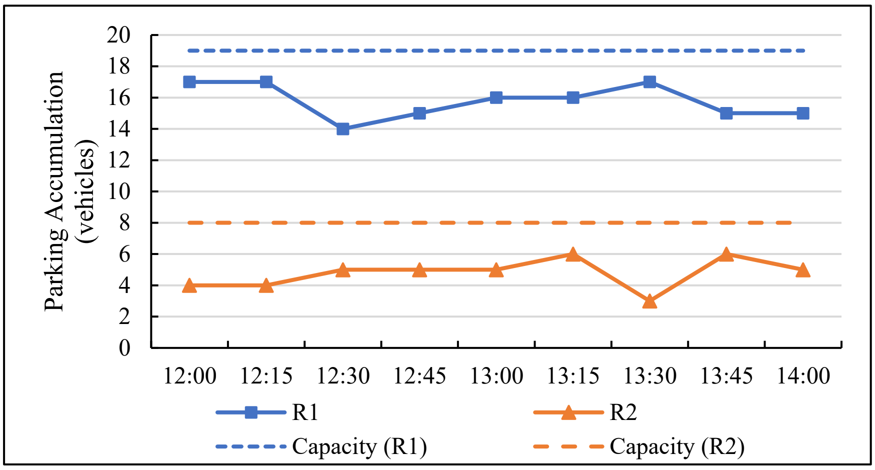

Figure 3. Parking Accumulation

Table 1. Results of parking study

Parking measure	R1	R2
Parking volume [veh]	95	32
Number of parking spaces available	19	8
Parking space turnover [veh/space/2 hours]	5.0	4.0
Parking duration per vehicle [min]	22.4	20.2

5. RESULTS

5.1 Trip generation

According to the TMH 17 (South African Trip Data Manual) (Committee of Transport Officials, 2013), fast-food restaurants with drive-through facilities will generate 200 trips per day per 100 m2 GLA and 20 trips per hour per 100 m2 GLA during the peak service hour (Committee of Transport Officials, 2013). The GLA of R1 and R2 are 350 m² and 250 m², respectively. Daily trip generation of R1 and R2 are calculated in *Table 2*.

The actual observed peak hour trips are also provided in *Table 2* for comparative purposes. Actual peak hour trips were calculated by adding the number of vehicles entering the drive-through to the parking volume in the 2 hours observed, divided by 2 (for a single hour). The parking volume at R1 was halved because the parking spaces serve both the convenience store and the restaurant. 70% of the vehicles arriving at the fast-food restaurants in Stellenbosch used the drive-through (68% for R1 and 72% for R2). This is slightly higher than the approximately 60% of people preferring the drive-through in the USA (Hill et al., 2016; Christina A Roberto et al., 2010).

Table 1. Trip generation estimates

	DAILY		PEAK HOUR	
	R1	R2	R1	R2
Trip Gen. Rate per 100m²	200		20	
Number of trips generated	700	500	70	50
Actual trips observed	-	-	75	58

The trip generation results and actual observations of trip arrivals during the operational peak hour are very similar. The daily trip generation estimates according to TMH 17 for both restaurants are therefore considered an accurate representation of actual daily traffic. The South Africa trip generation rates echo the those determined at fast-food restaurants in Malaysia (21.04 trips per 100m2 GLA) (Ahmed et al., 2014) and Abu Dhabi (19.53 trips per 100m2 GLA) (Al-Madadhah & Imam, 2020). Interestingly, these rates are about half of the trip generation rate used in the USA for fast-food restaurants (42.87 trips per 100m2 GLA) (Al-Madadhah & Imam, 2020).

5.2 Fuel consumption

Fuel consumption of vehicles using the drive-through at R1 and R2 were calculated over a 24-hour period using daily trip estimates. A daily total of 490 vehicles are anticipated to use the R1 drive-through and 350 vehicles at R2 (70% of daily trips).

A simplistic approach to fuel consumption is followed and acceleration and number of stopping and starting episodes are not modelled. Fuel consumption was calculated for only two modes while queuing: idling and slow moving. Fuel consumption is directly related to the gear and speed in which the car is driven. Fuel usage is highest in low gear and at low speeds (Nasir et al., 2014). Vehicles travel very slowly through the drive-through zone due to the queue of vehicles, stop-start movement at service points and narrow circulating lanes. Speeds of between 10 and 20 km/h in the drive-

through zone are typical and cars will remain in first gear while in this space, resulting in an average fuel consumption of 14 L/100 km (Nasir et al., 2014).

Fuel consumption of an idling vehicle is dependent only on time. Akçelik, et al. (Akcelik, Smit, & Besley, 2012) recommend using an idle fuel consumption rate of 0.361 ml/s for a standard petrol vehicle with an engine capacity of 1.4 to 2.0 L.

The total fuel consumption (FC), in milliliters, of a petrol vehicle while in a drive-through is therefore described by Equation 1, where D is the length of the drive-through (in m) and T is the time spent idling (in seconds).

$$FC_T = 0.14\mathrm{D} + 0.361T \qquad (1)$$

According to the assumption that vehicles move through the drive-through zone at an average speed of 15 km/h, a drive-time of 22 seconds for R1 (90 m long drive-through) and 29 seconds for R2 (120 m long drive-through) is applied. The remainder of the time spent at the drive-through is assumed to be spent idling. Using these assumptions, the average fuel consumption per vehicle is estimated in Table 3 for both drive-throughs, using the observed average time per vehicle. Assuming 490 vehicles a day use the R1 drive-through and 350 vehicles use R2, the total fuel consumption per year for just these two drive-throughs in Stellenbosch amounts to 27.3 KL (an average of 13.65 KL/facility).

Table 3. Fuel Consumption per drive-through

	R1	**R2**
Drive-through Length (m)	90	120
Average time in drive-through (sec)	216	253
Time spent idling T (sec)	194	224
Fuel Consumption per vehicle (ml/veh)	82.63	97.66
Vehicles per day using drive-through	490	350
Daily Fuel Consumption (L/day)	40.5	34.2
Annual Fuel Consumption (KL/annum)	14.78	12.48

5.3 Vehicle emissions

When vehicles idle, the engine does not operate at optimal temperature and so the combustion process is often incomplete (Rahman et al., 2013). This results in more emissions and traces of fuel residue during idling. The amount of Carbon Monoxide (CO), Nitrogen Oxides (NOx) and Hydrocarbons (HC) released per minute while a vehicle is idling is summarized in *Table 4* according to the USA Office of Transportation and Air Quality (Quality, 2008). Additionally, Carbon Dioxide (CO2) is released during the combustion process according to the fuel consumption. Every liter of fuel used by a petrol car results in approximately 2.35 kg of CO2 (Akcelik, Smit, & Besley, 2012).

According to the assumption that all vehicles using the drive-throughs in Stellenbosch are petrol vehicles with an engine capacity of between 1.4 and 2.0 L, just these two drive-throughs will generate 3.4 kg of CO and 150 kg of CO2 per day. This results in 1.25 tons of CO, 62 kg of NOx, 55 kg of HC and 64 tons of CO2 per year from only two drive-throughs.

Table 2. Vehicle emissions generated by Stellenbosch drive-throughs

Pollutant	**Factor**	**Unit**	**Emissions per day (kg)**			**Total Annual Emissions (kg)**
			R1	R2	Total	
CO	1.187	g/min idling	1.88	1.55	3.43	1 252
NO_x	0.059	g/min idling	0.09	0.08	0.17	62
HC	0.053	g/min idling	0.08	0.07	0.15	55
CO_2	2.35	kg/L FC	95.15	80.33	175.48	64 051

5.4 Equivalent parking for drive-through load

While the emissions load and fuel use at drive-throughs is substantial, these facilities do reduce the parking requirements of fast-food restaurants. This allows higher utilization of land for revenue generating purposes and reduces hard surfacing. To establish the space saved by drive-throughs, additional parking requirements were estimated.

The total number of parking spaces available, N, is related to the parking supply S according to Equation 2 (Garber & Hoel, 2014), where T is the time that each parking space i is available and f is an efficiency factor. f = 0.9 is assumed, indicating frequently used parking. Adequate parking is provided when parking supply equals demand, D calculated by Equation 3, relating the number of vehicles, n, to the time they spend parked, t, per parking space, i.

$$S = f \sum_{i=1}^{N} T_i \quad (2)$$

$$D = \sum_{i=1}^{N} (n_i t_i) \quad (3)$$

The additional number of parking spaces that would be required at R1 and R2 if the drive-through facilities were removed are calculated in *Table 5*. It is assumed that patrons who would have used the drive-through will not sit down at the restaurant and will therefore only spend 10 minutes ordering and collecting food for take-away. This is about half the time that parked vehicles currently stay at these restaurants. The additional parking is estimated for the peak 2 hours (T = 2 hours). Total parking load and 19 available parking spaces are used for R1 to ensure that current parking demand for the shared area, including the convenience shop, is accounted for.

Table 3. Additional parking requirements to account for drive-through

	R1		**R2**	
	Parking	Drive-through	Parking	Drive-through
n: number of vehicles	95	102	32	83
t: parked time (min)	22.4	10	20.2	10
D = S (space-hours)	52.47		24.61	
N: parking spaces required	29.15 ≈ 30		13.67 ≈ 14	
Actual number of parking spaces	19		8	
New parking spaces required	11 (58% of available)		6 (75% of available)	

The additional parking spaces needed to remove the drive-throughs and still serve all patrons is between 60 and 75% of the current parking provision (11 additional spaces at R1 and 6 additional spaces at R2). The drive-through circulation lane cannot be directly converted to parking due to inadequate space for circulation. Additionally, drive-through circulation lanes are often positioned along property boundaries within the building line, occupying otherwise unusable space that cannot be used for permanent structures. The consideration of additional parking and comparing parking area to the drive-through circulation lane is therefore specific to each restaurant site. Drive-throughs clearly reduce the land area required for a fast-food restaurant, which is of economic benefit to franchisees (Baxter & Stafford, 1985).

5.5 Limitations and suggestions for future research

The sample size of this study (two fast-food restaurants in one city in South Africa) is small, however, is in line with international research studies on drive-through operations which considered between 1 and 3 restaurants each (Hill et al., 2016; Mattingly et al., 2009; Baxter & Stafford, 1985). Additionally, the results of this study are aligned with trip generation, time spent in the drive-through and percentage vehicles using the drive-throughs determined in previous studies, indicating that the sample is reasonable.

The aspects investigated in this study (fuel consumption, emissions, and reduced parking associated with a drive-through), are considered in isolation and comparative indicators are not developed to allow comparison between the results. If, for example, a monetary cost was developed for fuel, CO2 emissions and land area cost, then an economic evaluation of the trade-off between environmental and space saving concerns could be discussed. This however fell outside the scope of this study which is intended to stimulate discussion of the sustainability of drive-throughs by quantifying the rather shocking fuel usage (13.65 KL/drive-through/year) and emissions (32 tons CO2/drive-through/year). Additionally, the cost of land and fuel costs between countries are highly variable, making a widely applicable study complicated. It is however, recommended that future studies consider an economic comparison in more detail.

An environmental analysis of the energy consumption of a fast-food restaurant with and without a drive-through would also be beneficial and is recommended for future research. This comparison could investigate the full environmental load associated with excluding a drive-through at a fast-food restaurant. This may entail reduction to emissions and fuel use (a significant environmental saving), but would result in increased parking requirement, resulting in more impermeable surface area and less open space for vegetation, linked to increased urban heat island effect (Qingming Zhan et al., 2020). Additionally, more patrons entering the restaurant area may require a larger building area (a capital cost) and increased building energy consumption. A comprehensive environmental investigation of energy consumption and heat generation would be useful in evaluating if the parking-saving aspects of a drive-through would balance the additional emissions and fuel consumption.

6. DISCUSSION

The fuel usage and emissions generated by drive-throughs is clearly a horrific waste of resources and needless contributor to pollution according to the outcome of this study. However, drive-throughs have also proven to reduce parking area requirements and result in higher revenue generation for franchisees. Of course, the conversation that we should be having is not one where we evaluate the benefits of doing away with drive-throughs in favor of additional parking for private vehicles, but in favor of trips made to restaurants by NMT or public transport. Urban planners in developing countries need to take cognizance of urban form that is openly aimed towards private car travel, as this, together with lack of competitive public transport options are driving the rapid increase in private vehicle use by the steadily growing middle-class in developing countries (A.Vasconcellos, 1997). Currently, private vehicle usage, while a growing concern and contributor to significant congestion in developing countries, is still relatively low. For example, in South Africa, private vehicle trips comprise 26.0% of trips, compared to 30.9% by public transport, and 41.7% by walking (SA, 2021). It is important to act towards sustainable land use forms as a matter of urgency to avoid additional mode share by cars.

Vasconcellos (1997) supposed that the only position that could convince drivers that have obtained cars according to the sociological model (which views cars as a necessary utility) to change to sustainable modes of transport is to apply pressure regarding environmental aspects of private vehicle use. Additionally, the mindset of developers, fast food franchisees, planning authorities and even political parties will need to change from capitalist modernization trends and planning paradigms that promote car use in order to achieve relaxation of the sociological trend towards private car demand (A.Vasconcellos, 1997). Consumers, however, must be willing to change their transport patterns. The importance of consumer buy-in is clear from examples of the few municipal areas in Canada and the USA where new drive-throughs are no longer being approved for development (Nykiforuk et al., 2018). This policy change has been met with public disapproval and disdain (Wida, 2019). The public are skeptical that this ban on new drive-throughs will result in environmental improvements and do not wish to lose the convenience of drive-throughs. Any change in drive-through planning should therefore be accompanied by a thorough marketing campaign indicating the emissions and fuel load of drive-throughs estimated in studies such as this one. It is significant that only 27 municipalities in Canada (of 3669 municipalities) have implemented by-laws banning new drive-throughs in the 14 years between 2002 (when the first bylaw was ratified) and 2016 (Nykiforuk et al., 2018).

The disappearance of drive-throughs in the near future is therefore unlikely, given the public desire for these facilities, the planning paradigms informed by capitalist and car-centric urban planning methods, the desire to own and use a private vehicle (particularly in the developing country context as per the sociological model of car demand), and the economic benefit for franchisees. Urban planners and developers should therefore implement innovative ways to improve the operation of drive-throughs to mitigate at least the environmental impact directly associated with idling vehicles, while we wait for an urban form paradigm shift. Papers such as this should pave the way for discussion and identification of future research that will

ultimately result in such a paradigm shift to more sustainable transport and urban design modes.

Two models that can reduce vehicle idling time at drive-throughs were presented in Chapter 2.3, Dougherty's "passive and active queuing system" and Whiting and Weckman's "parking slots" system. These models are applied to R2 in Figures 4 and 5 to investigate possibility of retrofitting the geometric design of a drive-through in accordance with the alternative service models. Both models resulted in improvements in all aspects of drive-through operation when implemented (Whiting & Weckman, 2004; MarkDougherty, 1997); however investigation of the impact of these models on waiting time, service time, fuel consumption and emissions should be carried out to evaluate their impacts in the developing country context in future research.

The application of Dougherty's (MarkDougherty, 1997) passive and active queueing system at R2 is presented in *Figure 4*. The stop line and signal head should be positioned to create an active queue section with a maximum of three vehicles that will be allowed to idle while waiting to order food. A loop detector could be placed at the menu board which will call a change of the signal to green when no more vehicles are waiting at the order point. The "parking slots" layout (Whiting & Weckman, 2004) as it could be applied at R2 is presented in *Figure 5*. The only changes required are the inclusion of 4 parking bays before the exit of the drive-through lane and a door to allow servers to deliver food to the waiting cars. These figures indicate that minimal changes, which can easily be incorporated with the current design of the R2 drive-through, are required to upgrade the standard drive-through service model to more sustainable forms.

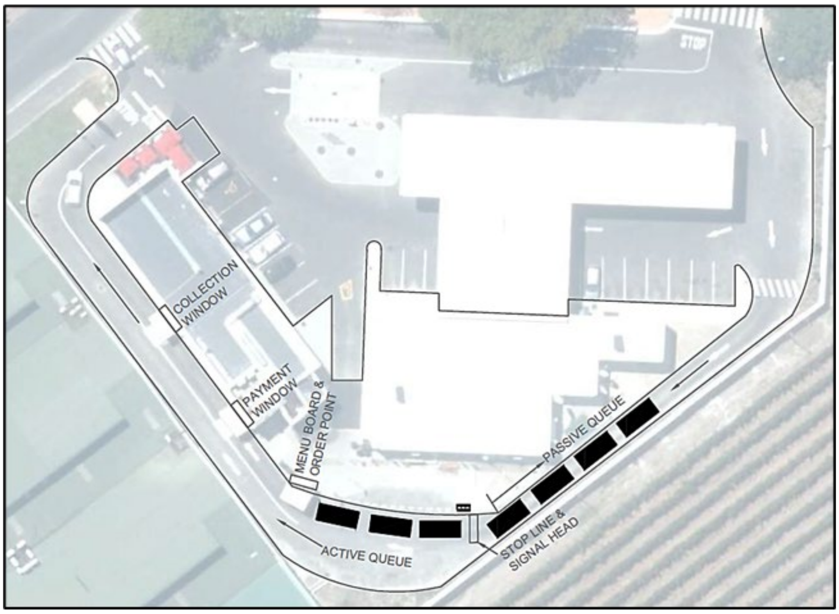

Figure 4. Passive and active queue system applied to R2

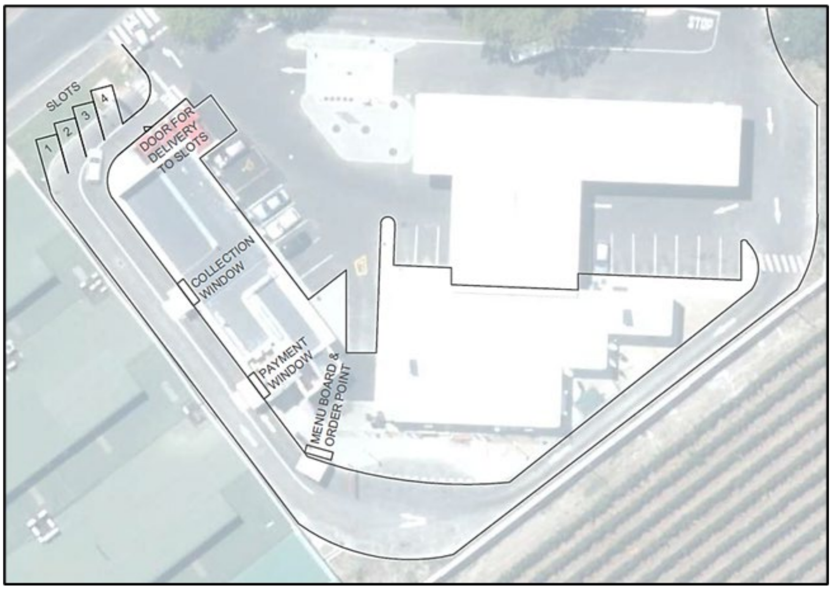

Figure 5. "Parking slots" drive-through layout applied to R2

7. CONCLUSION AND RECOMMENDATIONS

The primary goal of this paper is to stimulate discussion among urban planners in developing countries about the impact of the urban form, such as fast-food drive-throughs on encouraging private vehicle use. Development is required, however in the context of the trend towards private vehicle demand in developing countries and the need to address climate change, we should be cautious of perpetuating unsustainable transport modes.

Research relating to drive-through impacts are all USA-based, and only considered the negative impacts of excess fuel usage and emissions generated when using drive-throughs. This paper considered drive-through operations in a developing country (South Africa) and investigated parking requirements, which are drastically reduced by incorporating a drive-

through. This study found that parking provision would need to be increased by between 60 and 75% to accommodate additional parked vehicles if drive-throughs were closed. Additionally, the parking demand reduction that is afforded by a drive-through may reduce land requirement and hard landscaping space in a large parking area, resulting in more intense urban heat.

Drive-throughs do however have a substantial environmental cost, even with lower trip generation potential in the developing country context. The two fast-food restaurants investigated in this study (McDonald's and KFC) jointly generate 1200 trips daily, with 70% of these trips using the drive-through facilities. The idling and slow stop-start movement of these vehicles result in 175 kg of CO2 emissions per day, or 64 tons of CO2 per annum, as well as 1.25 tons of CO, 62 kg of NOx and 55 kg of HC per year. In addition, drivers cumulatively use 27.3 KL of fuel per year for the convenience of staying in their vehicles while ordering food from just these two restaurants.

Even considering this environmental impact, drive-throughs are still unlikely to be phased out on a large scale any time soon for space and economic reasons. Additionally, patrons are unhappy to lose access to convenience and are doubtful that environmental impacts will be decreased by removal of drive-throughs, as indicated from Canadian interventions. A balanced approach and alternative solutions are therefore needed to ensure that the environmental load of drive-throughs is minimized, while still providing for the convenience. Retrofitting existing drive-throughs should be widely possible according to two models to improve efficiency and reduce idling time at drive-throughs: the "passive and active queue system" and the "parking slots" system. For new drive-throughs and where space allows, fast-food franchises should be encouraged to incorporate a "parking slots" systems which has been shows to reduce vehicle "Time in System" during peak operation by allowing vehicles to effectively pass one another in the queue. It is recommended that these interventions be considered during the Traffic Impact Assessment phase of all new fast-food restaurants with proposed drive-through facilities.

Alternative drive-through strategies may improve the environmental load of drive-throughs; however, they will continue to perpetuate the sociological model of private vehicle demand. It is vital that the urban planning paradigm in developing countries is revamped to encourage public transport and NMT so that the need for private transport is reversed. Converting fast-food restaurants with drive-throughs to restaurants that encourage walk-in patrons may go some way to achieving this goal.

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