THE USE OF COAXS IN TSHWANE TO COMMUNICATE TRANSPORT IMPACTS IN STAKEHOLDER ENGAGEMENT

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ABSTRACT

Collaborative Accessibility-based Stakeholder Engagement (CoAXs) is an interactive planning tool intended to enhance public participation in planning public transport systems. To assess its applicability in various contexts, it has been implemented in the United States, in Chile, and, as presented in this paper, in Tshwane, South Africa. Tshwane is two years behind its plans to expand the A Re Yeng Bus Rapid Transit (BRT) network, largely due to initial resistance by private vehicle users to the city's Line 2B expansion plan. Using an adapted version of CoAXs that allows users to create scenarios by selecting Line 2B route options and visualise the corresponding accessibility impacts, four public engagement workshops were conducted in July 2018 in Tshwane. Using surveys and observations during the workshops, this study finds that CoAXs moderately broadened the users' scope of expected impacts of the BRT route options and prompted different user groups, especially private vehicle users, to empathize with users of other transport modes. CoAXs was effective in facilitating and supporting public engagement conversations, although more understanding and consideration of the variation in appetite for such engagements across interest groups and over the project timeline will be helpful in the future.

1. INTRODUCTION

Public transport development often involves multiple stakeholders with conflicting interests, which makes effective public engagement a critical part of the planning processes. Tshwane is undergoing such a planning process to expand its Bus Rapid Transit (BRT) network. A basic conflict exists between public transport commuters' urgent need for affordable and reliable services, and private vehicle users' concern about worsening traffic congestion. This conflict, combined with constrained road spaces, has interrupted, for over two years, the implementation of the city's BRT plan.

CoAXs (Collaborative Accessibility-based Stakeholder Engagement) is an interactive planning tool intended to enhance public participation in planning public transport systems. It features an accessibility-based visualization of project impacts under hypothetical scenarios that are modifiable by its users. CoAXs has been successfully tested in the

United States and Chile, showing potential for broadening project understanding and fostering empathy among different stakeholders (Stewart, 2017, Navas, 2017).

This paper presents an experiment with an adapted version of CoAXs for application in Tshwane. The study aims to determine whether: a) the visualization of accessibility changes influences the public's perception of, and attitudes towards the addition of BRT routes; b) the visualization helps develop empathy among transport user groups with conflicting interests, i.e., public transport users and private vehicle drivers; and, c) the tool is useful in supporting stakeholder engagements for public transport planning in Tshwane. The relevant data was collected through a series of facilitated workshops with community members in the city, all hosted in July 2018. Workshop participants made use of the tool to visualise hypothetical scenarios of the BRT expansion in Tshwane, and various data collection methods were used in each workshop to capture shifts in participants' perceptions and attitudes towards the BRT, as well as their perceptions of the tool. The Tshwane project was a collaboration between the Massachusetts Institute of Technology and the University of Pretoria, undertaken as part of the BRT+ Centre of Excellence.

2. CoAXs: BACKGROUND AND TSHWANE ADAPTATION

CoAXs is an interactive collaborative planning tool with a user interface that makes use of accessibility metrics to visually communicate the impacts of current and/or hypothetical public transport scenarios. Accessibility describes the ease or difficulty of reaching a destination or opportunity from a particular location (Venter, Cross 2014). CoAXs makes use of accessibility metrics because several studies have shown that accessibility provides a more holistic approach to transportation planning and analysis. Furthermore, these metrics can act as evaluation criteria when making a selection between alternative transportation projects or plans (Morris et al., 1979, Cervero, 2005)

CoAXs was developed by a team at MIT to provide a way for stakeholders to collaboratively and interactively explore the accessibility impacts of possible changes to current or planned public transport networks. Through several years of evolution, CoAXs is now a front-end interface that receives users' modifications to transit scenarios, requests accessibility calculations from the Conveyal Analysis[1] backend, and represents the results in the form of isochrones and related statistics of selected opportunities (e.g. jobs, schools, healthcare facilities etc.) within those isochrones. A specific CoAXs instance (for a particular city) can be built with the input of three types of data specific to the context: Open Street Map (OSM) network of the region, the General Transit Feed Specification (GTFS) of the transit routes, and georeferenced data of opportunities.

The first version of CoAXs was developed by Anson Stewart in 2014 (Stewart, 2014). It has since been developed and adapted to analyse the accessibility impacts of various hypothetical transport scenarios by incorporating an editor that allows for modifications of frequency, dwell times, routes and other service parameters (Stewart & Zegras, 2016). Using pre- and post- workshop surveys and video recordings at CoAXs workshops conducted in Boston, Stewart (2017) found that social learning was enabled by the ability to test and compare accessibility impacts from different locations relevant to different users. Furthermore, the tool was adapted to not only compare accessibility isochrones of hypothetical transport scenarios from a specified origin (*accessibility version*), but also to compare the travel time savings/gains of specified origin-destination pairs (*point-to-point*

[1] Conveyal Analysis is an open source software for visualising accessibility under different public transport scenarios (see https://www.conveyal.com/analysis). CoAXs use the server component of Conveyal Analysis as its backend.

version). Through workshops conducted in Boston, it was discovered that users of the *accessibility version* had greater shifts away from their initial expectations of some impacts. The *accessibility version* also helped foster greater focus on others' trips, although the *point-to-point version* was rated higher in terms of usability (Stewart, 2017).
The *accessibility version* of CoAXs was selected for use in Tshwane. The hypothetical public transport scenarios evaluated using the tool were related to the BRT and its proposed Line 2B expansion (between Hatfield and Menlyn) as this was a relevant and highly contentious topic at the time that this study was planned. CoAXs requires GTFS feeds of the public transport routes in the region, which are relatively data intensive and therefore more suited to formalised modes of transport with fixed routes, frequencies, and stops. In Tshwane, this data was only readily available for the BRT.

Accessibility was visualised as an isochrone – a geographical area within which a user could travel on the BRT within a specified time period from a specified origin. The aggregate number of opportunities (in this case, jobs) that fell within the generated isochrone was also shown to the user. Workshop participants could interact with the interface by (un)selecting routes, adjusting the travel time constraint (defining the isochrones boundary), and specifying any origin of choice when comparing various scenarios of the BRT implementation.

2.1 The contentious Line 2B of the A Re Yeng BRT

In July 2012, the City of Tshwane started construction of its BRT system, *A Re Yeng*, with the first phase of the system becoming fully operational in December 2014 as a trunk-feeder structure. Figure 1 illustrates the completed and planned trunk routes for *A Re Yeng*. Currently, the Pretoria BRT consists of 2 trunk routes and 7 feeder routes. The completed and operational trunk routes are Line 1A and Line 2A in Figure 1. They have a total length of 16 kilometres, with 12 stations, and run through the Pretoria CBD on dedicated lanes, with enclosed median stations located along the routes. The feeder routes run across the city to bring passengers to the trunk route, mostly in mixed traffic lanes. The complete system is planned to have 16 trunk lines, with a total length of 80 kilometres, and 62 stations, among which 5 trunk lines (53 kilometres total) are planned to be implemented by 2022. The fare structure of *A Re Yeng* is distance-based, with a tap-in – tap-out payment system via pre-loaded cards.

In 2012, the city conducted a feasibility study of the impacts of converting one of the two mixed traffic lanes to a dedicated bus lane in each direction of Lynnwood Road and Atterbury Road (two major arterials in Tshwane) to accommodate the proposed Line 2B trunk buses. The study concluded that, aside from the Lynnwood and University Road intersection, the reconfiguration of two lanes (one per direction) to dedicated bus lanes would not result in considerable congestion at other intersections along the route. The city then released this feasibility study to support the planned lane conversions on the arterials (Moatshe, 2017). However, independent transport engineers conducted a subsequent analysis and found that most of the intersections on Lynnwood Road already experience significant congestion in the morning peak period; they concluded that the results of the initial feasibility study were implausible (Pretoria News, 2015). The local residents, who experience the congestion, quickly started to oppose the city's plan (Bothma, 2015). This conflict remained unresolved for over two years, and in January 2018, six months after the date that Line 2B was originally planned to be operational, the city announced its decision to maintain two mixed traffic lanes per direction on Lynnwood and Atterbury Road so that the introduction of Line 2B will not compromise existing road capacity for mixed traffic.

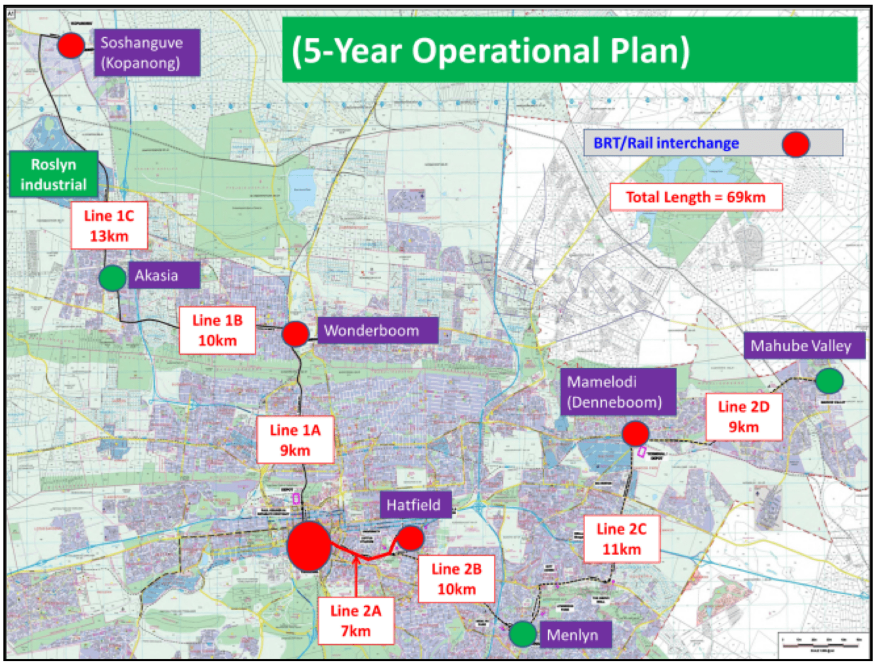


Figure 1: A Re Yeng BRT 5 year operational plan (Vadi, 2017)

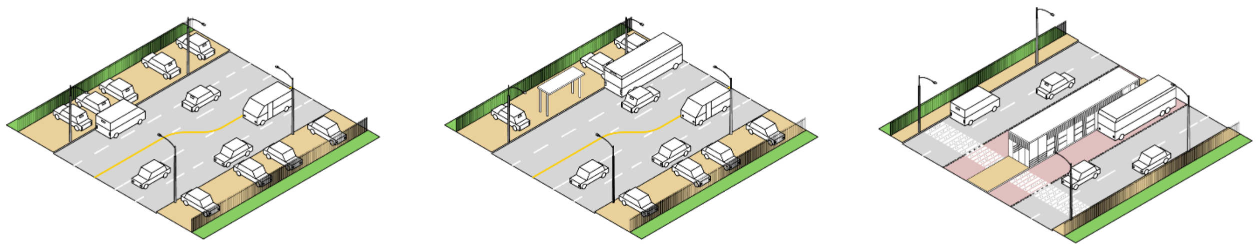
2.2 Tshwane CoAXs scenarios

Following the decision to maintain existing road capacity for mixed traffic, two options existed for the Line 2B route: a) operate the BRT in mixed traffic, with no major infrastructure construction, or b) construct a new lane in each direction, for exclusive BRT use.

Presumably, these two options will have very different impacts on different user groups. Option A would minimally impact private vehicle users (given low bus frequencies of no more than 8 buses per hour), but the travel time benefits of the BRT for bus riders would be compromised. Option B would benefit the BRT users with greater travel time savings and reliability by isolating services from congestion. However, parking capacity for private vehicle users along Lynnwood Road outside the University of Pretoria would be compromised (as parking spaces would be lost for the new bus lanes). Furthermore, Option B is more capital intensive than Option A, and it is uncertain if commuters would be required to bear this cost in terms of increased fares. The Tshwane CoAXs was adapted to compare the following three trunk scenarios:

1. **Baseline scenario**: the fully operational existing BRT, which includes Line 1A, Line 2A, and the associated feeders;
2. **Baseline scenario + Line 2B in mixed traffic**: considering the addition of Line 2B to the existing network, with Line 2B operating in mixed traffic;
3. **Baseline scenario + Line 2B in a dedicated bus lane**: considering the addition of Line 2B to the existing network, with Line 2B operating in a dedicated bus lane.

Figure 2 illustrates the street configurations of the trunk route scenarios along Lynnwood Road outside the University of Pretoria. The current street consists of two mixed traffic lanes in each direction, with additional turning lanes at intersections, and parking on shoulders. For the mixed traffic scenario of the Line 2B addition, parking spaces could be removed at places where BRT stations need to be located, and buses will travel in the mixed traffic lanes with all other vehicles. For the dedicated bus lane scenario, parking spaces on each side will be removed along the entire alignment, while the sidewalk will remain, and a bus lane dedicated to the BRT and separated from general traffic lanes by barriers will be added. The dedicated bus lane addition was conceptualised as a bus lane located in the median lanes of each direction, with enclosed median stations along the route.



(a) Existing Lynnwood Road (b) Line 2B - Mixed traffic scenario (c) Line 2B - Dedicated lane scenario

Figure 2: Schematic of various Line 2B scenarios on Lynnwood Road

During preparation of the scenarios, discussions with city officials raised the issue of the first-last mile, and the importance of the bus feeder routes that would connect surrounding neighbourhoods with the BRT trunk. Subsequently, the local team created six hypothetical feeder routes based on their knowledge of the area, the existing feeder routes for Lines 1A and 2A, and the existing routes of other bus services operating in the area (Figure 3).

The Tshwane CoAXs instance was designed such that users can select any of the trunk route scenarios, as well as any combination of the six feeder routes, and CoAXs generates the associated isochrones. Feeder routes can only be selected if a Line 2B trunk route scenarios is selected.

The opportunity dataset was obtained in shapefile format from the Council for Scientific and Industrial Research (CSIR). This dataset represents the number of jobs in 2014, across various sectors, in Tshwane's 243 Transport Analysis Zones (TAZs).

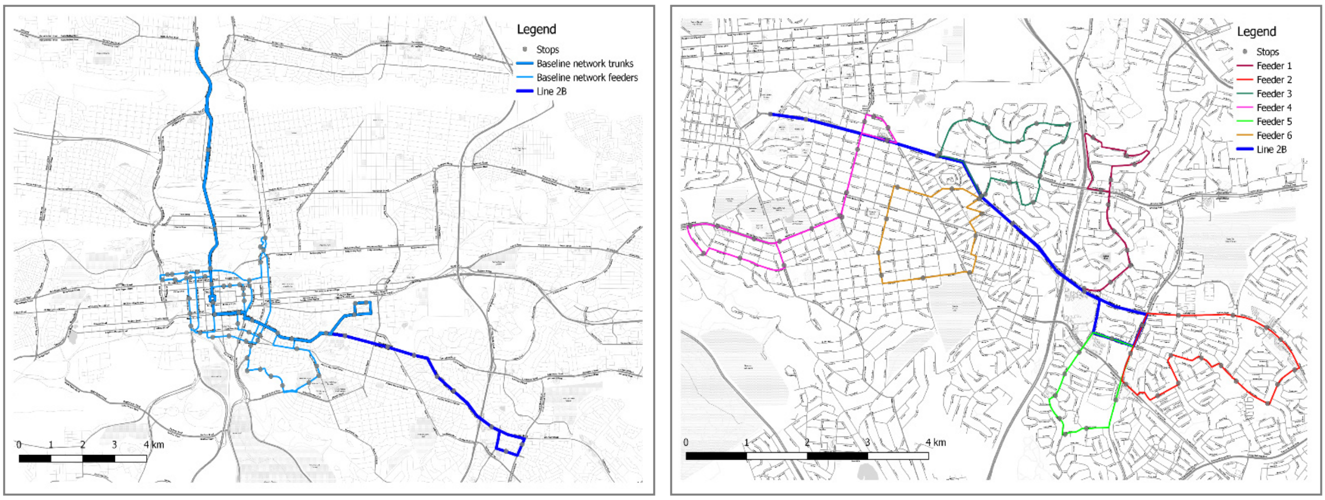


Figure 3: Map of hypothetical Line 2B route and associated feeder routes

2.2.1 Assumptions

For simplicity and clarity, a number of assumptions were made when defining route specifications. Since the benefits of a BRT operating on a dedicated lane are most evident when traffic is most congested, all the calculations are based on travel speeds during the morning peak period. It was also assumed that the average travel speed of BRT in the

Line 2B dedicated bus lane scenario is similar to the average travel speeds on Line 1A and Line 2B. For the feeder routes and the Line 2B mixed traffic scenario, it was assumed that the BRT travel speeds are similar to the travel speeds of the existing feeder routes for Line 1A and Line 2A. Finally, it was assumed that the morning peak frequencies of Line 2B and its feeder routes are similar to the frequencies of the existing routes and feeders. Refer to Table 1.

Table 1: Scenario route assumptions

Route	Description	Speed (km/h)	Number of stops	Headway (minutes)
Line 2B mixed traffic	Hatfield ↔ Menlyn	15	16	7
Line 2B dedicated lane	Hatfield ↔ Menlyn	25	16	7
Feeder 1	Menlyn ↔ Lynburn Road	15	11	15
Feeder 2	Menlyn ↔ Atterbury Value Mart	15	15	15
Feeder 3	Lynnwood Road ↔ Kings Highway	15	12	15
Feeder 4	Hatfield ↔ Brooklyn	15	16	15
Feeder 5	Menlyn ↔ Newlands	15	9	15
Feeder 6	Atterbury ↔ Menlo Park	15	10	15

2.2.2 Limitations

Since public transport affordability is a persistent challenge in South Africa, especially amongst public transport users, it would have been appropriate to depict accessibility not just as a function of travel time but also of travel cost. Unfortunately the backend (Conveyal Analysis) capability to calculate travel cost surfaces was not developed in time for the Tshwane workshops. The possibility to allow for travel time comparisons between private vehicles and the BRT Line 2B scenarios was also considered, as it would provide an intuitive visualization of the benefits of the BRT on a dedicated bus lane against a do-nothing scenario. However, development of this feature was restricted by the fact that reliable private vehicle travel time matrices during peak periods were unavailable.

2.3 Tshwane CoAXs interface

Figure 4 displays a screenshot of the CoAXs Tshwane interface. The interface has a map as the main component, with a movable pin representing the user-selected origin point for generating the isochrones. To help users find locations on the map, major points of interest such as landmarks, institutions, and public amenities are shown on the map. A panel on the right-hand side has a scenario editing area, a scenario summary table, a slider for setting the time constraint, and a bar chart area showing the scenario results as the number of jobs accessible in the specified time-frame. The isochrones are recalculated either when a user clicks the “Update” button or moves the origin pin.

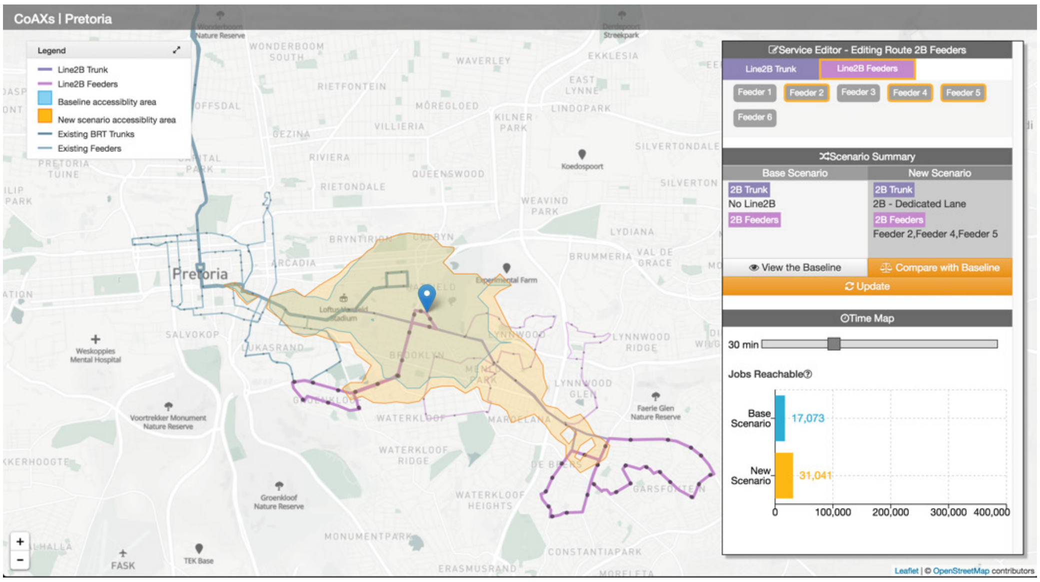


Figure 4: Tshwane CoAXs user interface

3. FACILITATED WORKSHOPS

Four workshops with local residents were held in July 2018 in Tshwane. These workshops were designed drawing from the experiences of previous workshops in Boston and Santiago de Chile, with modifications according to the Tshwane context. The first two workshops were largely comprised of residents of surrounding neighbourhoods, and the last two workshops largely comprised of students residing in and around Hatfield.

In each workshop, a 60-inch touch screen was used for group interaction with the tool (refer to Figure 5). The participants were asked to leave their seats and gather around the screen during the scenario analysis session. Figure 5 displays the setup at the first workshop, including seating layout during presentation (upper) and scenario analysis session at the touch screen (lower).

Figure 5: Workshop layout at NG Lynnwood church

Two types of data collection methods were designed and implemented in the Tshwane experiments: quantitative data from pre- and post-workshop surveys, and qualitative data from workshop observations and facilitated discussions. Questions in the surveys were designed to capture participants' perceptions and attitudes in the following aspects before and after using the tool: a) understanding of the public transport projects being discussed; b) expected impacts of proposed public transport projects, with questions specific to each trunk route scenario; and, c) attitudes to the proposed public transport projects and enthusiasm in using or advocating for them.

The pre-workshop survey also collected participants' basic information, including occupation, education and income level, commute modes, and experience with community engagement meetings. The post-workshop survey asked participants to evaluate the usability of CoAXs and its usefulness for public participation in transport planning.

Qualitative data collection during workshop discussions focused on participants' feedback on the scenarios, the tool, and the workshop in comparison with traditional public meetings regarding similar issues. Follow-up interviews were also carried out with two of the participants, a ward councillor and a city official, to obtain more detailed information on traditional community engagement meetings.

4. RESULTS

4.1 Observation and facilitated discussion outcomes

The four workshops recruited 33 participants in total. Among these, 31 provided valid survey responses. Based on the reported most frequent mode of commute, the participants are divided into two categories: 15 car users and 16 non-car users. Participants at the first two workshops were mostly car users (10 out of 11), while the majority of participants at the last two workshops were non-car users (15 out of 22).

Discussions in the workshops were mainly facilitated by sociologists, with intermittent input from the Univ. of Pretoria and MIT CoAXs team members. Table 2 summarises the feedback from the different participant demographics. Participants in the first two workshops had prior understanding of the project as some have been involved in the Line 2B debate for years, and are familiar with transport planning topics. In contrast, most participants at the last two workshops did not have prior knowledge of the project, or transportation planning in general, therefore, their discussions were mostly from the perspective of a layperson/user.

During discussions of the projects, all participants in all workshops agreed that the proposed BRT route is currently not located to reach the neighbourhoods most in need. Participants specifically identified townships such as Soshanguve and Mamelodi to be the areas that would benefit the most from BRT as an affordable commuting service. Comparing feedback from the different workshops, participants in the first two workshops focused more on broader issues related to impacts of the additional BRT route, such as densification and congestion. Discussions during the last two workshops focused more on the characteristics of the additional BRT route, such as frequency and bus types. As for feedback on CoAXs and the workshops, participants in all four workshops agreed that CoAXs is helpful in a public consultation setting for decision-making. Furthermore, there were common suggestions for broader participant involvement and additional tool features, such as integration with other transit modes and cost-constrained accessibility.

Table 2: Summarized participant feedback during facilitated discussions

Workshop	Feedback on the Projects	Feedback on CoAXs and Workshop
Workshops 1&2 **Predominantly car users**	Potential densification along the trunk route will be a concern of people living in those areas. Line 2B is located away from the much busier routes with greater need. It would be more beneficial to the city to incorporate and/or improve the existing transport network rather than introducing a new BRT system. Resistance from the taxi industry is a big challenge to the success of BRT. Addition of Line 2B trunk route will lead to congestion if there is no dedicated bus lane.	Better marketing and advertising are key to improving attendance to these workshops. Public meetings usually attract people with complaints only. Appreciated that the tool not only focuses on transport but also socio-economic activities. It would be helpful to show direct comparison between isochrones in the dedicated bus lane scenario vs. mixed traffic scenario. The tool would be of better use if it is incorporated earlier in the decision-making stage.
Workshops 3&4 **Predominantly non-car users**	The BRT system needs to improve frequency and speed on the trunk lines. Comfort of the buses will be key to attracting motorists to leave their private cars and switch to the BRT. Integration with existing public transport networks will not be effective unless ticketing and fares are well integrated.	The visualizations could be enhanced if 3D, satellite & street view, and more graphs are incorporated. The workshop helped clarify the BRT scenarios, and improve knowledge on transport related issues in planning. CoAXs could be developed into an end-user mobile app, showing areas accessible from users' locations, different from existing point-to-point navigation apps. Real-time bus location and information could be incorporated in the app. User interface needs to be simpler for general users to get started quickly.

4.2 Survey analysis

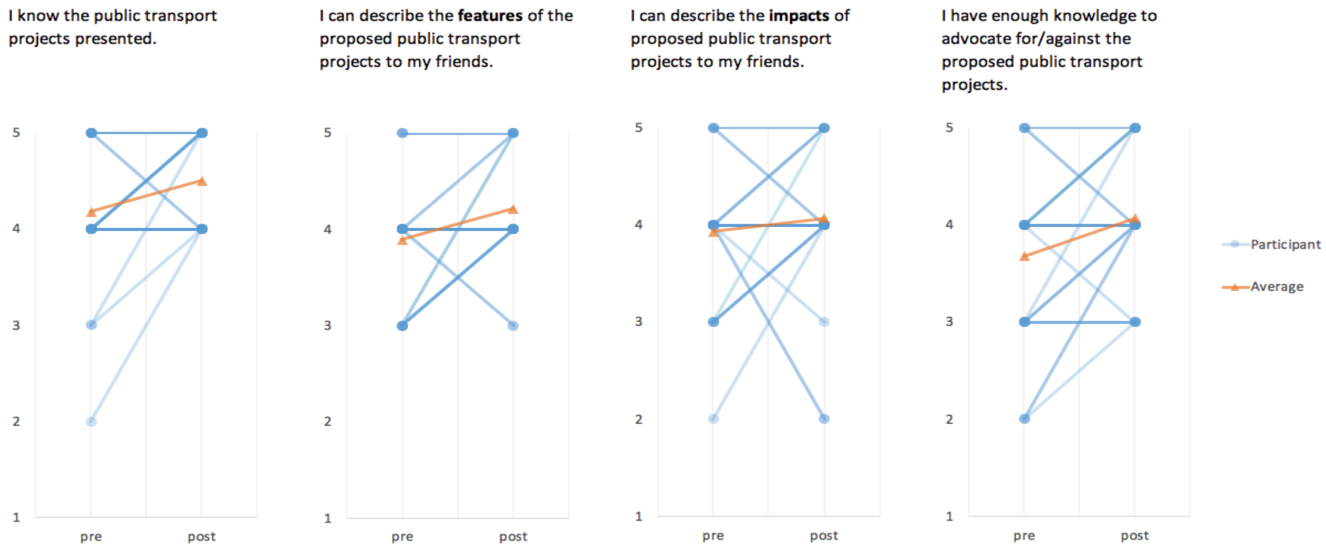
Questions in the survey are mostly choice questions using a five-point Likert scale, where 1 means strongly disagree with the provided statement or "very negative impact" for the specified group or scope, and 5 means strongly agree or "very positive impact". Analysis of the survey responses focuses on four main topics: 1) project understanding, 2) expected project impacts, 3) attitudes and enthusiasm, and 4) tool usability and usefulness. To measure the shifts from before and after the workshops in responses to questions regarding the first three topics, tilted line-segment plots and associated percentages of participants in different shift categories (i.e., positively shift, no shift, and negative shift) are used to illustrate the shifts directly. The Wilcoxon signed-rank test is also used to test the null hypothesis that the median response did not shift. It is applied to all participants and the two user groups (car users and non-car users) separately.

In addition, differences in responses to questions regarding expected project impacts and attitudes and enthusiasm between the two groups are also tested and compared. Mann-Whitney *U* tests are used to test the null hypotheses that the distributions of the pre-workshop scores are identical between the two user groups, and the distributions of post-workshop scores are identical between the two user groups. Then the results from the pre- and post-workshop tests are compared to see if the two groups came in with different expectations or attitudes but had similar expectations or attitudes after the workshop, or vice versa.

4.2.1 Change in participant perceptions and attitudes

Project Understanding

All four questions (see Figure 6) about project understanding receive increased average scores after the workshop, although the improvement in being able to "describe the impacts" is not statistically significant. For all questions, among the participants who have shifted scores, more of them have positive shifts. These results suggest that CoAXs is effective in improving participants' general understanding of the projects, knowledge of the project features, and knowledge to advocate for or against the projects.



	I know the public transport projects presented.	I can describe the features of the proposed public transport projects to my friends.	I can describe the impacts of proposed public transport projects to my friends.	I have enough knowledge to advocate for/against the proposed public transport projects.
Average score (pre)	4.18	3.89	3.93	3.68
Average score (post)	4.50	4.21	4.07	4.07
Shift	0.32	0.32	0.14	0.39
Positive shift	32%	32%	32%	39%
No shift	61%	61%	50%	50%
Negative shift	7%	7%	18%	11%
p-value (Wilcoxon)	0.03301	0.03301	0.4905	0.02364

Figure 6: Shifts in project understanding

Expected Project Impacts

Participants' expectations about project impacts are measured by the question: "what impact do you think the two scenarios of expanding A Re Yeng between Hatfield and Menlyn will have on the following individuals or groups?" This differs from their response in being able to "describe the impacts" as it measures how participants expect the project to impact various groups, rather than their perception of their ability to describe these impacts. Table 3 summarizes the average scores for responses in both the pre- and post-workshop surveys. The higher the score, the more positive the expectation.

Table 3: Summary of average score for impacts of two trunk line scenarios

	Pre-workshop			Post-workshop		
	Dedicated lane	Mixed traffic	*difference*	Dedicated lane	Mixed traffic	*difference*
Yourself	3.692	2.692	*	3.731	2.885	*
Your neighbourhood	3.462	2.808	*	3.731	2.885	*
Other neighbourhoods	3.308	2.808	*	3.885	3.000	*
Your city	3.800	2.880	*	4.200	2.800	*
Pedestrians	3.500	2.893	*	3.679	3.071	*
Cyclists	2.778	2.815		3.222	2.852	
Private vehicle users	2.571	2.500		2.964	2.536	
Public transport users	4.357	3.393	*	4.393	3.179	*
People with disabilities	4.074	3.185	*	4.074	3.370	*

Note: "difference" column represents whether the difference between the two scenarios (dedicated lane versus mixed traffic) is statistically (*) significant ($\alpha = 0.05$) using a Wilcoxon signed-rank test.

Before and after using CoAXs, participants generally had significantly more positive expectations about impacts of the dedicated lane scenario than the mixed traffic scenario. In both surveys and in both scenarios, participants had the most negative expectation of impacts on private vehicle users.

Looking at changes in the expected project impacts from pre- to post-workshop, for both scenarios, more people indicated no shift than positive or negative shifts in expected impacts on almost all of the above mentioned groups. The average score shifts are only significant for the expected impacts on very few groups – *other neighbourhoods* and *cyclists* in the dedicated scenario (see Figure 7). Both significant shifts are positive, meaning participants had more positive expectation of impacts on these groups after the workshop than before it. Participants' expected impacts of the dedicated lane scenario on themselves, their neighbourhood, the city, pedestrians, private vehicle users, and public transport users all slightly shifted positive, although this shift is not statistically significant. In contrast, expected impacts of the mixed traffic scenario on the city and public transport users have insignificant negative shifts (see Figure 7), meaning that the initial expected positive impacts of the mixed traffic scenario on these two groups tended to turn negative after the workshops. Specifically, the downward shift in the expected impacts on public transport users was more noticeable (0.21) with 39% of participants shifting negative; this may suggest participants' disappointment when seeing relatively limited increase in accessible regions when the mixed traffic scenario was selected.

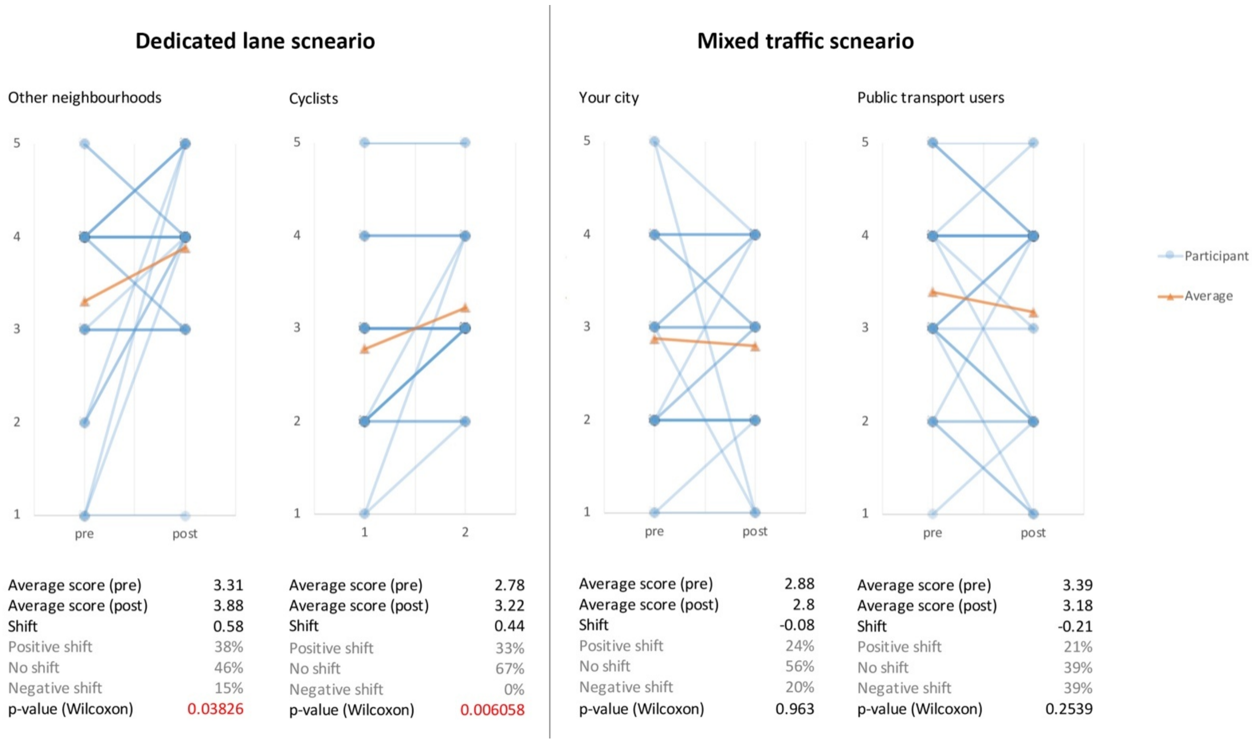


Figure 7: Overall shifts of expected impacts of dedicated lane and mixed traffic scenarios

Attitudes and Enthusiasm

Participants' attitudes and enthusiasm towards the proposed projects are measured by their responses to statements about whether the projects help achieve transportation goals and broader urban goals. In addition to this, participants were asked whether they would be willing to use the proposed BRT route, or to let their children use it, or to advocate for it. Responses to the statement "I would be willing to let my children use the proposed Line 2B BRT to commute" show a significant negative shift (-0.32, p = .04 in the Wilcoxon test). This may indicate that safety is an important consideration for parents, particularly with regard to their children walking to and waiting at bus stops. However, the tool only visualises accessibility with no indication of associated safety hazards. Other noticeable, although not statistically significant, shifts include a negative shift in participants' agreement with the statement that the proposed Line 2B will effectively improve transportation in the city (-0.26, *p* = .11); this is consistent with comments made in all workshops that Line 2B is not at the most needed location or integrated with other modes. However, responses to the statement that the proposed Line 2B will help advance important broader urban goals indicate a slight positive shift (+0.19, *p* = .21), which suggests that participants were able to understand the broader impacts of the project through the workshops. This is in alignment with participants' increased expectations about impacts on the city. Furthermore, participants' agreement with the statement that "I would be willing to use the proposed Line 2B BRT to commute" indicated a small negative shift (-0.15, *p* = .65), which also aligns with the previously discussed disappointment with limited observed improvements to accessibility in the mixed traffic scenario. For all the questions in this section of the survey, the majority of participants did not shift in their responses. This suggests that using CoAXs in these workshops had a generally limited impact on changing participants' attitudes and enthusiasm.

4.2.2 Empathy-building between user groups

Looking at shifts in project impact expectations for the two user groups separately, in the dedicated lane scenario (see Table 4) car users have significantly positive shifts in expected impacts on the city (+0.67, *p* = .06 in the Wilcoxon test), cyclists (+0.50, *p* = .03), and private vehicle users (+0.67, *p* = .04), while non-car users' expected impacts do not have significant shifts. This suggests that the car users' negative expectations of the proposed BRT route are somewhat alleviated after using CoAXs in the dedicated lane scenario. The improved expectations of impacts on the city and cyclists may be an indicator of a broader understanding of potential impacts brought by BRT, and a growing empathy towards commuters using other modes.

Table 4: Pre- and post-workshop comparison of expected impacts between user groups (dedicated lane scenario)

		Yourself	Your city	Private vehicle users	Public transport users
Pre-workshop	Average score (Car users)	3.33	3.46	2.13	4.13
	Average score (non-car users)	4.13	4.20	2.93	4.67
	p-value (Mann-Whitney)	*0.0043*	*0.0016*	*0.0563*	*0.0626*
Post-workshop	Average score (Car users)	3.43 (+0.10)	**4.13 (+0.67)**	**2.80 (+0.67)**	4.20 (+0.07)
	Average score (non-car users)	4.08 (-0.05)	4.17 (-0.03)	3.15 (+0.22)	4.62 (-0.05)
	p-value (Mann-Whitney)	*0.0283*	0.8789	0.4741	0.229

Note: Numbers in italics represent statistically significant ($\alpha = 0.1$) differences between the two user groups (car users versus non-car users) from Man-Whitney U tests. Numbers in brackets represent shifts of average scores from pre- to post-workshop responses, and bold numbers in brackets represent statistically significant ($\alpha = 0.1$) shifts from Wilcoxon signed-rank tests.

Table 4 shows that the two groups' expected impacts of the dedicated lane scenario on themselves, the city, private vehicle users, and public transport users tended to converge after the workshops (i.e., shifting from differences with a more significant *p*-value to a less significant or insignificant one).[2] The car users started with much lower expectation of the impacts on themselves than the non-car users, while after using CoAXs, the car users had a slightly more positive expectation while the non-car users had a slightly more negative

[2] There was no significant difference in responses from the two user groups in expected impacts on any of the impact categories in the mixed traffic scenario.

expectation. This change may indicate disappointment among non-car users seeing limited benefits to themselves. In addition, although the non-car users' expected impacts on themselves shifted negatively, their expectations of impacts on private vehicle users had a slightly positive shift (+0.22). This suggests that CoAXs helped non-car users see less adverse anticipated effects on the car users of the proposed project.

The effect of CoAXs in building empathy between user groups is also directly measured by post-workshop questions about whether CoAXs prompted participants to imagine travel alternatives for themselves and trips of others. A strong majority of participants agreed with the statements: "CoAXs helped me imagine what commute/travel is like for others" (24 out of 27) and "CoAXs prompted me to think about alternatives for my own commute/travel" (22 out of 26).

4.2.3 Usability and usefulness of CoAXs as a public engagement tool

CoAXs received positive ratings in general, with over 50% of participants indicating that they "agree" or "strongly agree" with all four statements regarding tool usability. About 25% of participants disagreed with the statement: "I would imagine that most people would learn to use CoAXs very quickly." Based on workshop experiences in Tshwane, proper introduction to the terms used in the tool and demonstration of usage are generally helpful in getting participants started and familiarized. The presence of staff to assist when users face problems is also necessary.

In terms of usefulness, participants expressed broad agreement that CoAXs could be useful in a public meeting setting to support teamwork and meaningful conversation. All respondents agreed with the statement that "I would imagine CoAXs to be a useful tool in future public meetings about proposed public transport improvements." Over 80% of participants agreed (and none disagreed) that "CoAXs helped raise important issues for discussion" and "CoAXs provided a useful common ground for all participants to work together." Lastly, over 80% of participants disagreed that "CoAXs distracted people from conversation."

5. CONCLUSIONS AND RECOMMENDATIONS

The objectives of the study were to determine whether: a) the visualization of accessibility changes influences the public's perception of, and attitudes towards, the addition of BRT routes; b) the visualization helps develop empathy among transport user groups with conflicting interests, i.e., public transit users and private vehicle drivers; and, c) the tool is useful in supporting stakeholder engagements for public transport planning in Tshwane.

First, the results suggest that CoAXs was effective in improving users' knowledge of the proposed BRT routes and moderately effective in broadening the scope of users' understanding of possible impacts of the proposed BRT routes across the entire city. However, it was not effective in improving users' attitudes towards the proposed BRT routes. Moreover, CoAXs may have negatively shifted workshop participants' attitudes to, and enthusiasm for, the proposed projects, by causing disappointment when showing accessibility improvements that did not meet the participants' initial expectations.

Second, CoAXs was effective in helping users, especially car users, to better understand the expected impacts of the proposed BRT routes on other user groups and, hence, helped foster empathy between car users and non-car users. This is supported by significant positive shifts in car users' expected impacts of the proposed BRT routes on users of other modes, and positive shifts in non-car users' expected impacts on car users, resulting in converged expectations between the two user groups. This is also supported by participants' agreement with the statement of "CoAXs helped me imagine what commute is like for others".

Finally, participants gave CoAXs high ratings regarding its usability and generally high ratings on its usefulness as a public engagement tool. This indicates that the adapted CoAXs instance for Tshwane was suitable for the context in fulfilling its intentions.

The experience of the Tshwane CoAXs deployment also provides recommendations for future implementation of similar tools in public engagement settings. Although the project teams intentionally included car users and non-car users in this experiment, overall the participants were generally well-educated and tech-savvy. Future implementations will benefit from including participants from more diverse socioeconomic and demographic groups, especially for projects related to lower-income communities. As many participants pointed out, a lot of the disappointment in these projects was a result of the late timing of these workshops in the decision-making process. Future public engagement workshops would be more attractive to the public and more successful if they take place at an earlier stage of the planning timeline. Moreover, although participants in this study did not encounter much technical difficulty, technical assistance at the workshops was identified as necessary for future implementation of digital tools in public engagement. Finally, in developing city contexts travel cost is often more of a binding constraint than travel time. The idea of developing an application that includes travel cost in its accessibility visualisation was supported by many workshop participants. Research is needed on how to best introduce this added level of complexity without compromising the effectiveness and usability of the tool.

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