Detail on Model

This supplementary material builds on Section 2.3 of the Full Paper. Please read this section and refer to Figure 4 for context.

Diffusion

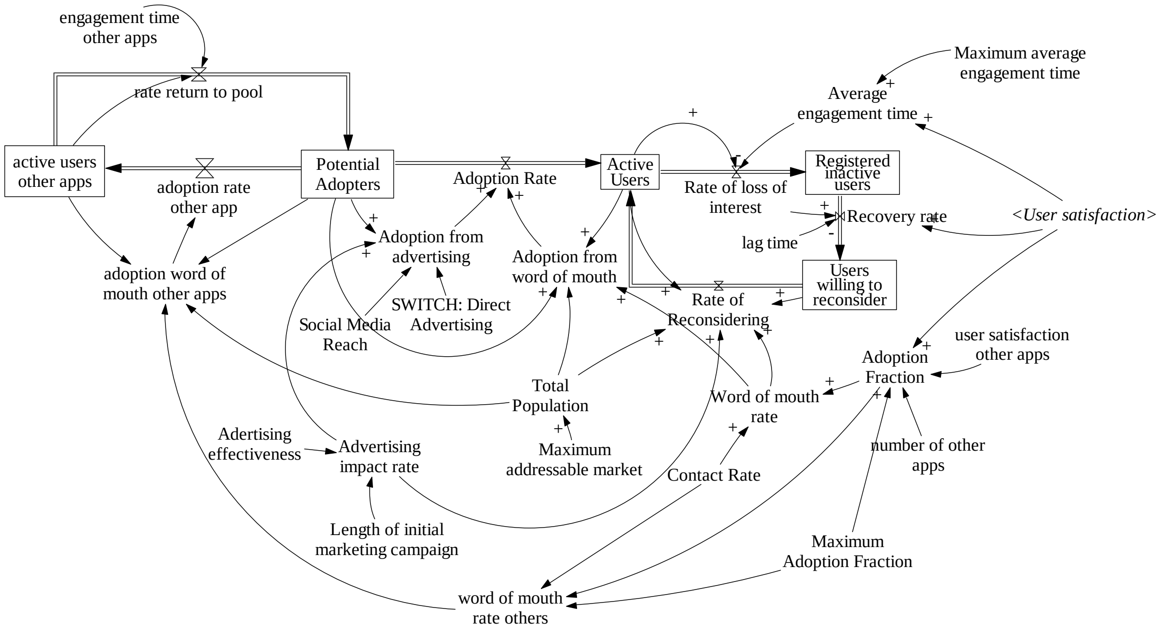

Figure S1: Diffusion functional area of the model, showing the extension for inactive users reconsidering use of Trav.ly and competition with other apps.

Reactivation of inactive users

The model was extended to allow users who stopped using the app to be re-engaged after a ‘cooling-off’ period (“lag time”), as shown in **Figure S1Error! Reference source not found.**. Lag time is set to 3 months. The rate of users reconsidering is then calculated using the same mechanism as for potential adopters who have not yet registered for the app, i.e. through advertising and word of mouth. However, previous users will be disgruntled to a certain level, i.e. user satisfaction below 100% reduces the effect of advertising and word of mouth proportionally. For testing purposes, the Total Population value can be reduced to just bus users from the Maximum addressable market, here 580,000 potential users in West Yorkshire. This is based on a scoping study carried out for the app, which segmented the West Yorkshire population (c. 2m) into their potential to use the app based on socio-demographics, attitudinal characteristics, access to public transport and access to a mobile phone [1]. Also for scenario testing, based on observed phenomena, the Adoption from advertising can be limited by *Market Reach*, which reflects the restricted reach if an advertising campaign is carried out through just through one channel (eg online).

Competition with other apps

In addition to users becoming inactive due to dis-satisfaction, potential adopters of the app could also be lost to competing apps offering similar functionality to Trav.ly. Although Trav.ly is the first app offering both journey planning and ticketing for West Yorkshire, there are numerous competing apps (and websites) available that offer one or other of these functions, as demonstrated in **Table 1**. Many people currently use a selection of these apps. Note that no app (identified by us) offers all functions for all modes. Thus, in a similar mechanism to adoption of the Trav.ly app, potential adopters could become an active user of a different app, influenced by the effect of word of mouth.

Table 1: Main competing free apps (and websites) available in West Yorkshire

	Name	Multimode	Journey planning	Real time	Track	Ticketing
Mobile Phone Apps	Moovit	ALL	✓	✓		
	UK Bus Checker	ALL	✓	✓		
	Trainline	Train	✓	✓		✓
	Northern Rail	Train	✓	✓	✓	✓
	National Express	Coach	✓		✓	✓
	M Card	Bus				✓
	First Bus	First Buses	✓	✓		✓
	Arriva	Arriva Buses	✓	✓		✓
Web	WY metro	Bus		✓		
	National rail	Train	✓	✓		✓

User Satisfaction

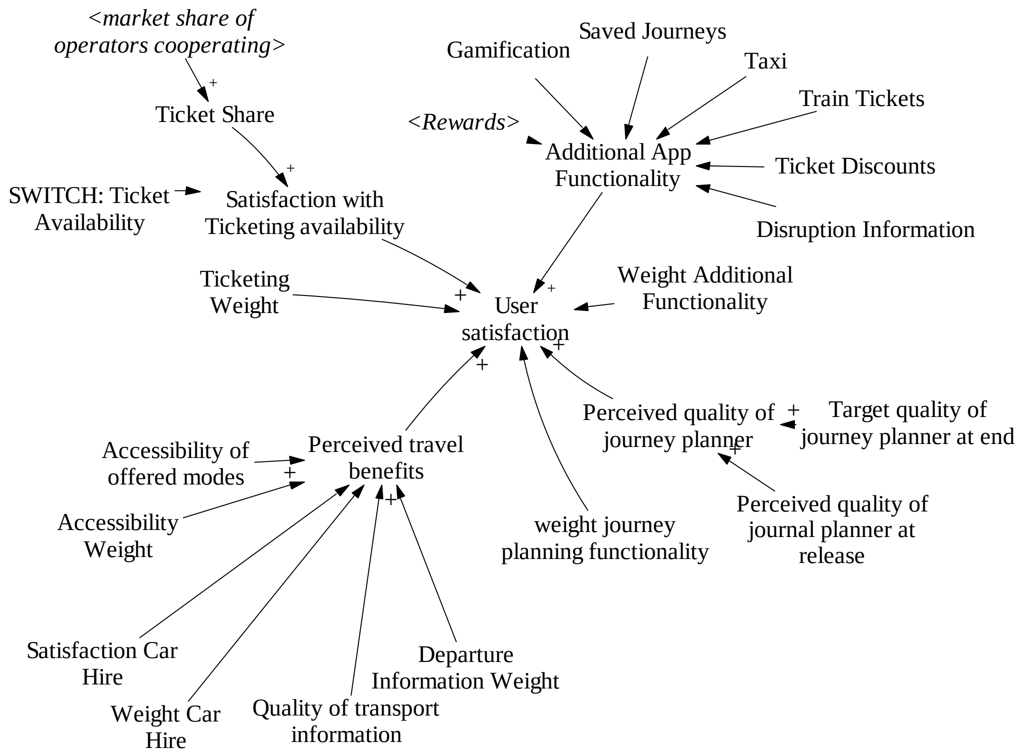

Figure S2: Model extension incorporating user satisfaction

User satisfaction is a key factor driving users' adoption of and engagement with products [2]. Besides pure utilitarian benefits of products, hedonic benefits play an important role driving this consumer satisfaction, in particular for smartphone applications [3,4]. Utilitarian benefits for users of the Trav.ly app are e.g. improved journey planning information leading to reduced travel times and costs or easier and quicker ticket purchasing mechanisms than with current solutions. Hedonic benefits are those related to an opportunity for self-expression, entertainment and exploration. For a smarter travel app this could include reward schemes for using the app, gamification elements such as recording travel activities in comparison to other users, or the option to communicate and interact with other users. The design of app features such as the included functionality, ease of use, user interface attractiveness, privacy and security, and portability influence both the utilitarian as well as hedonic benefits [5].

The influence of app functionality on user engagement and app usage has been studied for mobile travel and tourism apps that offer support for long distance travel and accommodation booking (e.g. [5,6]). However, there is less research available on what drives user engagement and satisfaction for mobile journey planning and ticketing apps for public and urban transport. For this reason, we are starting with a simple model where average engagement time is directly proportional to user satisfaction: if satisfaction is 100%, all users will keep using app for a maximum engagement time of 24 months and if less than 100%, engagement time will reduce by the same percentage. Minimum average engagement time is set to 1 day.

Satisfaction with ticketing availability

A key unique selling point for the app is the ability to purchase tickets for their trips through the app for multiple operators and modes (currently bus only). Users are assumed to be satisfied relative to the proportional availability of tickets in the app, i.e. the *ticket availability* of the many ticket types across West Yorkshire bus operators (see later) and the *market share of operators co-operating* by allowing their service to be purchased through the app.

Perceived quality of journey planner

The app will allow users to plan their trips for a variety of modes and ideally using real-time information. Satisfaction will depend on the functionality as well as ease of use. Linear increasing function starting from a specified perceived quality of the planner at release to a target quality of the journey planner that is available at the end of the simulation period. During initial model development it was thought that not all journey planning functions would be available, however in the released version of Trav.ly almost identical algorithms are used to main competing apps, so the quality at release is 100%. However this is kept in the model to allow for sensitivity and what-if testing.

Perceived travel benefits

This covers the utilitarian benefits of the app. Assumed is that users will only keep using it if they save time or costs. This is dependent on the *quality of the information* provided but also the *accessibility* of offered modes to the users. Additionally, *Car Hire* is included the Trav.ly app and assessed in the user survey so is included here. A simple average of the three factors is taken, all currently set to 1.

Additional functionality

All additional functions can be switched 'on' or 'off' by the model user for scenario testing, and are not included in the initially released version of Trav.ly. With the exception of *Rewards* (which was identified as being a particular function of interest in the scoping study so has functional detail within the model – see later), they are all assumed to be 100% when switched 'on'. There are two forms of optional functionalities of travel apps (which may already be available in similar competing apps), that are included in the model in order to study the uptake sensitivity: Incentives and Utility.

The importance of motivating users through incentives is e.g. shown in Fogg's Behaviour Model [7], and shown to be effective in transport related apps. Users are offered special benefits from using the app and reaching certain milestones. These can in principle be immaterial or material rewards. Three forms of incentivisation are represented:

- **REWARDS:** Direct material *Rewards* offered by sponsors such as free drinks.
- **GAMIFICATION:** Competitions with other users and social functions.
- **TICKET DISCOUNTS**: Special access to ticket discounts not available elsewhere.

There are also three utility functions which could further make the app more desirable to users:

- **TRAIN TICKETS:** The ultimate goal of the Trav.ly app is to offer truly seamless multi-modal journey planning and ticketing. At the initial release although train journeys were included in the planning the ticketing was not available.
- **TAXI:** A beta version of Trav.ly included a link to Uber. However, it was felt that this app should encourage more sustainable mobility and even if taxi's should be included then local services providing app booking should also be included.
- **SAVED JOURNEYS:** Many competing journey planning apps offer users the option of saving regular journeys to save time in planning.

App Usage

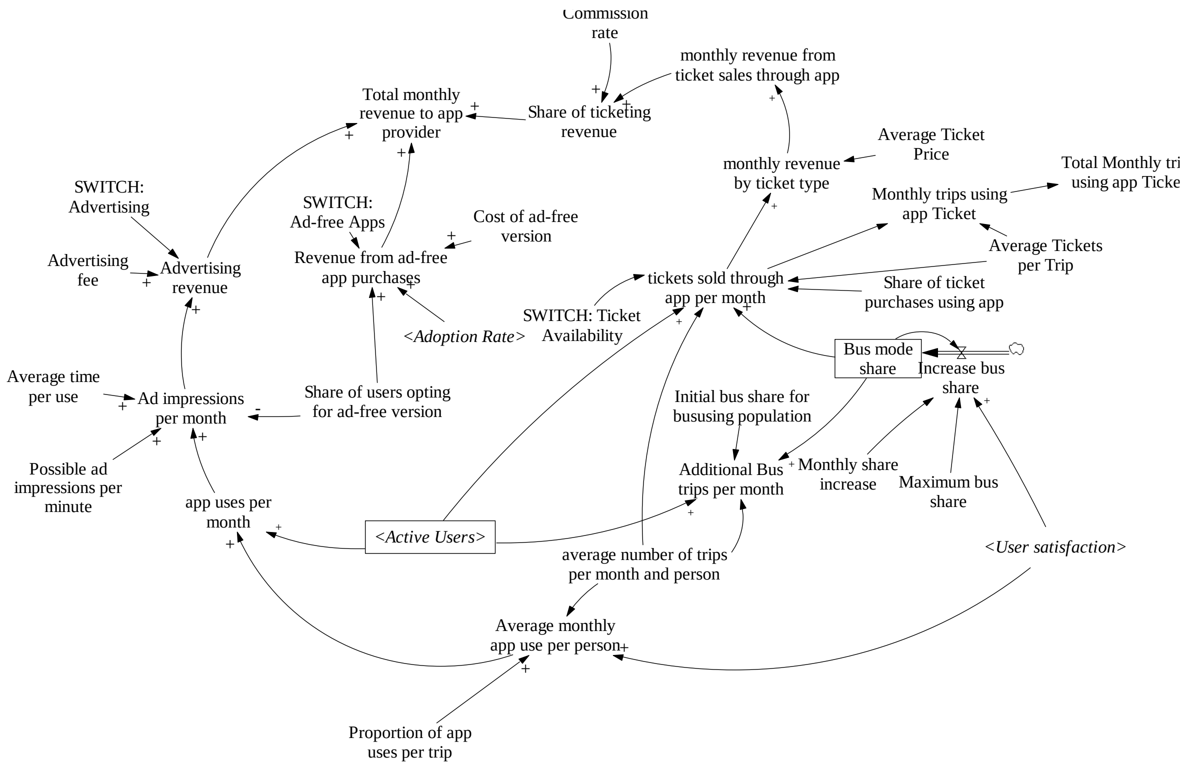

Figure S3: Functional area of the model for calculation of monthly uses and revenues from Trav.ly

App Usage

Very little data is available on actual use of journey planning apps. Roughly 15 Million public transport journeys were planned using the then publicly provided online UK journey planner "Transport Direct" between August 2010 and July 2011, which equates to less than 1% of all trips by public transport [8]. However, since then the quality and availability of journey planners particularly on smartphones has improved considerably. Hence, in order to calculate the total number of app uses per month we firstly assume that every user makes 68 trips a month. The average number of annual trips per person in Yorkshire & Humber in the period 2015/16 is 822 (excluding walks under 1 mile) [9], which is simply divided by 12 for a monthly average. Of these total trips, the app is assumed to be used in 25% of cases, i.e. almost once every working day (assuming 20 days a month) for which travel information is required. A prerequisite for such a high number is that the app offers benefits for daily use also for habitual trips such as commuting to work, e.g. through a reward system (if activated) or real-time disruption information. Lower user satisfaction proportionally reduces *average monthly use*. The number of *active users* therefore results in the *app uses per month.*

Ticketing

It was the original intention to include all bus and train ticketing for West Yorkshire, however, in our current model (and indeed the current app), only bus ticketing is included. At present, Trav.ly is restricted to offering only a multi-operator daily ticket ('MCard Day') – either as a single ticket or bundles of 3 or 5, and a Park and Ride ('P&R') return ticket (for two sites serving Leeds) – also as a single or bundles of 5, 10 or 20. The daily ticket is available at a discount price (from buying on bus) currently not available as a mobile ticket[1], and the P&R ticket is offered at a discount not available elsewhere. These represent only a very small amount of ticket sales in West Yorkshire. There are however, many other ticket types available across West Yorkshire, both as multi-operator and single operator tickets, and there is no central repository of sales data for all of these. Although this is thought to be in excess of 400 distinct types [10], we limit our ticket types to those set out in **Table 2**. These tickets can be restricted using an on/off 'switch' for testing purposes – eg our base case only includes the currently available ticket types of MCard Day or P&R. In our model, we do not consider annual or concessionary passes (ie seniors, students and children). We estimate with our project partners that these may account for approximately 50% of bus journeys, but it is assumed that offering these ticket types on the app would not give commercial advantage.

Table 2: Ticket Types included in the model

Parameter	Overall	P&R	MCard (Bus only)			Single Operator (Based on First WY)			
			Day	Week	Month	Single	Day	Week	Month
Average Ticket Price	Weighted by sales share	£2.775[1]	£5.125[2]	£23	£88	£2	£4.80	£20	£72
Average Tickets Per Trip[3]	Weighted by Sales Share	1/2	1/3	1/15	1/60	1	1/3	1/15	1/60
Average Tickets per Transaction	Weighted by Sales Share	9[5]	4.75[4]	1	1	1	1	1	1
Sales Share[2]	n/a	0.6%[5]	1.4%[6]	15%		83%			
				7.5%	7.5%	20%	20%	20%	20%

[1]Assumed 25% single (£3), 75% bundle (£2.70); [2]Assumed 25% single (£5.50), 25% bundle (£5); [3]Assumed work days only, 3 trips per work day; [4]Estimated by project partners; [5]Assumed equal transactions (single, 5/10/20 bundle); [6]Assumed equal transactions (single, 3/5 bundle)

The tickets sold through app per month, subscripted by ticket type, is a product of bus trips carried out by app users, average tickets per trip, share of tickets purchased through the app, ticket share and ticket availability. The total number of bus trips per month carried out by active app users is determined from the average number of trips and the bus mode share. We set the initial bus share of trips to 24%. This is based on 151 million bus trips a year carried out in West Yorkshire [11], shared across the average 822 total trips a year carried out by each of 778k people in West Yorkshire who could use the bus (using the same segmentation study as for the addressable population of the app without excluding those without mobile phones). Interestingly, this number also correlates with the national share of bus-user trips carried out by local bus [12]. This share can increase when user satisfaction of the app increases above 80%, but is assumed to not be able to rise any more than 10% of the starting value. As many ticket types can be used for multiple journeys, the total number of tickets is lower than the

[1] The discounted price is available to users with a physical 'MCard' that can only be topped up at travel centres, machines at bus stations or through a separate app.
[2] Estimated by project partners

number of trips, based on a number of average tickets per trip. This is subscripted by ticket type (see **Table 2**), and based on assumption of 2 trips per work day and 20 work days per month. The share of ticket purchases using the app is assumed to be 50% based on insights from project partners (though this may at present be aspirational). As not all tickets are currently available on the app, and this availability in turn affects satisfaction with the ticketing availability the number of tickets purchased through the app is reduced proportionally. As this is subscripted by ticket type, the ticket share of all bus trips, estimated by project partners, is also taken into account.

Revenue

Total monthly revenue for the app provider is then calculated as a sum of revenues from in-app advertising, app purchases (both of which are not available in the current version of Trav.ly but can be turned 'on' via a switch for 'what-if' scenarios) and ticket sales. The *Advertising revenue* for app provider (see top part of **Figure S3**) assumes that in-app advertising is provided during each use for users who did not opt to buy an ad-free version, resulting in a number of *possible ad impressions per months*. This is calculated as the number of *possible ad impressions per minute* (assumed that on average ads are shown for 30 secs, so set to 2) times the uses per month times the *average time per use*. According to [13] average usage time for travel apps such as Google Maps is 45 sec. For our case we assume this to be higher to allow for time to purchase tickets, hence set to 1 minute. According to [14] average advertising fees for in-app advertising vary between $1 and $10 for 1,000 ad impressions, hence we set the initial value £4 for our model. In our current model version we assume that any in-app advertising is designed in such a way that it does not have a negative impact on user satisfaction of those users who do not opt out.

Some users, however, might opt to purchase an ad-free version of the app. These users pay a one-off price after downloading the app, hence *Revenue from ad-free app purchases* is the product of the adoption rate, share of users opting for an ad-free version and the costs of the ad-free version. We assume that 5% of users would opt for an ad-free version, equivalent to the average of users paying for in-app purchases [15], and apply the current price of £3.99 for the ad-free version of a UK journey planning app at the time of model building (2017), Traveline. Although that app is no longer available, the average price of apps purchased is only slightly lower at around £3.50 (though we recognize the median price is half of that) [16].

Monthly revenue from ticket sales will be shared between the app provider and transport operators, with the app provider receiving a small share from commissioning. The *average ticket price* for a ticket purchased through the app is set out in **Table 2Error! Reference source not found.**. We further assume that the *commission rate* to calculate the *share of ticketing revenue* for the app operator is 3.5%, as advised by project partners.

Operators Co-Operating

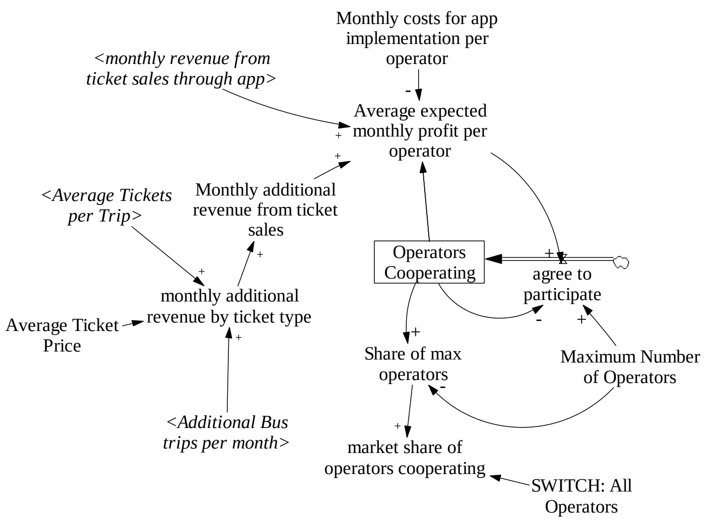

Figure 4: Operators co-operating functional area of the diffusion model

The *maximum number of operators* is set to 10. In reality, there are an estimated 34 bus and coach operators in West Yorkshire, however, the market share of the majority of operators is very small: The market share of bus vehicle trips within West Yorkshire is 54.8% for the largest operator, 25.5% for the second and 5.8% for the third largest [17]. Due to the lack of data we assumed the remaining market shares to be decreasing, resulting in the accumulated market shares as shown in **Figure 5**.

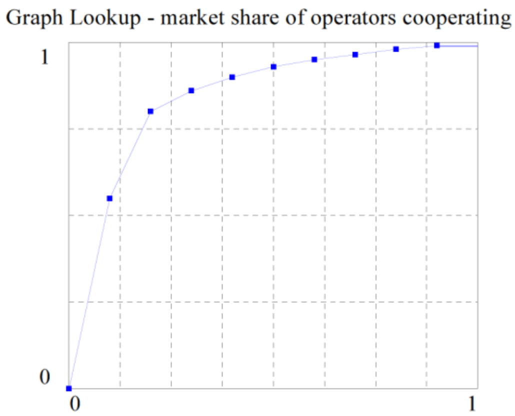

Figure 5: Cumulative market share depending on the share of number of operators

It is assumed that the largest operator is co-operating with Trav.ly from the start, as otherwise an important unique selling point of the app would be missing and it would not be brought onto the market. Further operators join the scheme in order of market shares. Operators do not leave scheme once they have joined. A new operator only agrees to co-operate if the *average expected profit per operator* from ticket sales covers the *monthly costs of implementation* of the scheme. The average expected profit is the revenue from ticket sales minus the commission for app provider minus the cost of implementation for operators divided by the number of operators. We assume that the *costs of implementation for the bus operators* are £1,000 per month, which includes e.g. training drivers to accept the mobile ticket. These decision processes and cost values are hypothetical based on informal discussions with project partners so require refinement in future models.

Rewards

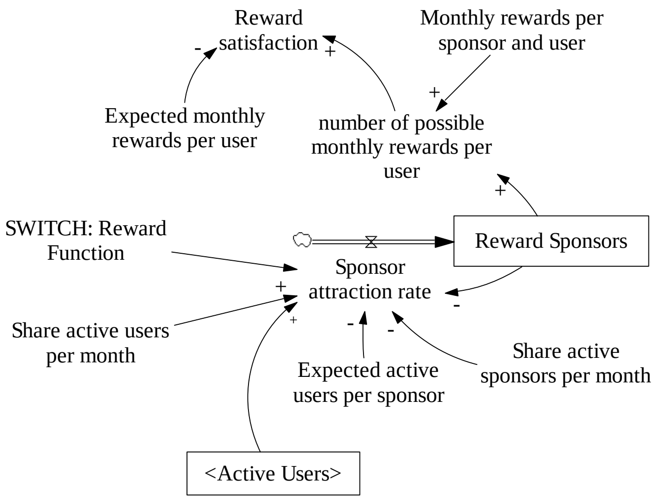

Figure 6: Reward sponsoring

It is assumed that a potential reward sponsor would agree to participate if the number of *expected monthly users per sponsor* exceeds a set value (assumed to be 50,000), i.e. the attraction rate is 1 if the number of monthly users divided by expected users is larger than the stock of already existing reward sponsors. Initially we assume that sponsors offer 1 reward per user per month, though part of these could be immaterial rewards. As mentioned previously, Rewards are turned off in our base case to reflect the Trav.ly functionality but can be turned on via a switch for 'what-if' scenario testing. We assume that users expect a certain number of *rewards per months*. Satisfaction is then calculated as a ratio between expected and *available rewards per user* with a maximum of 100%. The *Sponsor attraction rate* and thus number of *reward sponsors* is determined by the number of *active users.*

Profitability

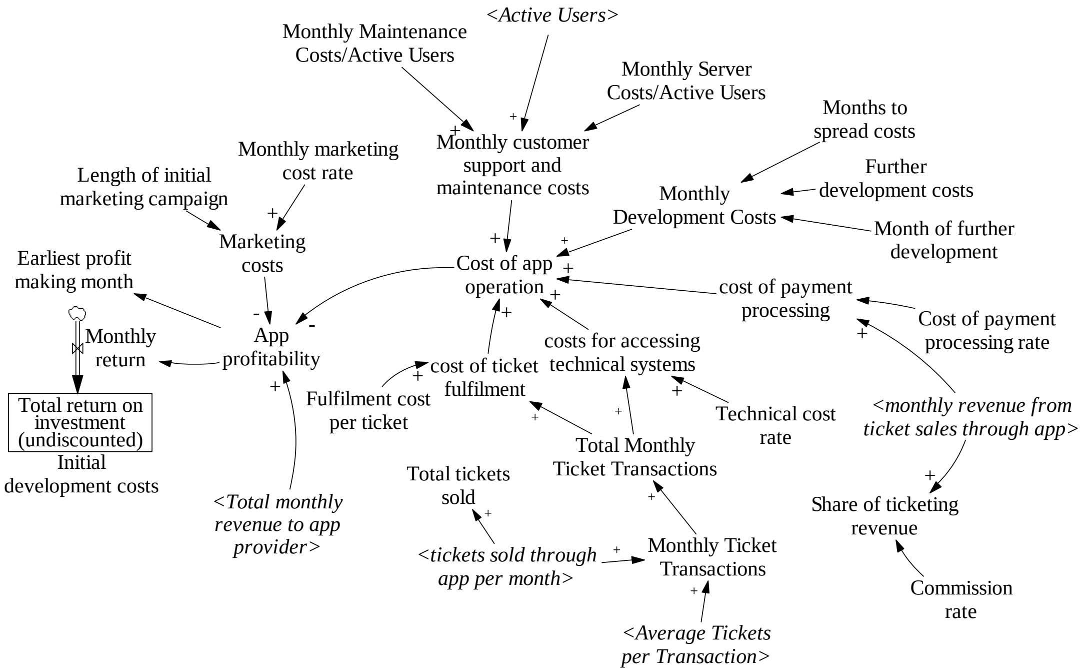

Figure 7: Operating costs and app operating profitability

Ticket fulfilment

These are charged for each electronic booking for tickets to cover costs of operators arising e.g. through collection from a vending machine, installing bar code readers or similar. The rail industry charges £0.40 per ticket for collection from vending machines [18], however as there is no equivalent for bus tickets this is set to 0 in the base case. This is based on the number of *ticket transactions* rather than directly from tickets, as some tickets are available as multi-ticket bundles.

Payment processing

Retailers typically have to cover costs of electronic payment which can be between 0.5% and 3% [18] plus any costs arising in case of fraud or refund claims. The *payment cost rate* is set to the 2% of the ticketing revenue as advised by project partners.

Accessing technical systems

According to [18], third party retailers in the rail market are usually charged a small fee to access industry systems, e.g. to search for ticket options. In the base case this is set to 0 as it is assumed to be covered by server costs. This is based on the number of *ticket transactions* rather than directly from tickets, as some tickets are available as multi-ticket bundles.

Customer support and maintenance

This consists of two elements – maintenance costs to continue providing high quality services and server costs for technical hosting of the app. Trav.ly app developers estimate monthly maintenance costs of £3000, rising to 5000 once there are over 150k users, and monthly server costs of £150, rising to £3000 for 150k users.

Marketing

smartinsights [19] estimate the marketing costs per install (CPI) to $1.2-$1.6 depending on which markets are targeted and platforms used. Marketing costs assumed to be at lower end of range (CPI of £1) for relatively small target area and set to £17,500 per month of campaign

Monthly development

Providing additional functionalities (such as rewards), requires additional funding, but this can be spread out across the months of operation. In the base model we do not include any development of this type.

Model Base Scenario Constants

Name	Value	Unit	Description	Source
Accessibility of offered modes	100%	dmnl	Dummy factor at the moment, factor thought to influence travel benefits, dependent on spatial access	Assumption
Accessibility weight	0.05	dmnl	Weighting to Accessibility of offered modes. Current estimate.	Assumption
Advertising effectiveness	1.5%	persons/ persons/ month	Share of population downloading app per month after seeing advertising; medium effective assumed	[20](based on [21])

Advertising fee	0.004	£ / ad impressions	Average fee for in-app advertising $4 for 1000 ad impressions, range between $1 and $10	[14]
Average number of trips/person/month	68	Trip (month* person)	Number of annual trips per person excluding walking less than 1 mile = 822. (divided by 12 months)	[9]
Average ticket price [Ticket Type]	MCard Day = MCard Day Average Price MCard Week = 23 MCard Month =88 PnR = PnR average price Operator Single = 2 Operator Day = 4.80 Operator Week = 20 Operator Month = 72	£	MCard Week and Month = current price of bus only (June 2018); Operator tickets = current price of First Bus WY (June 2018)	MCard (www.m-card.co.uk) and First (www.firstgroup.com) websites
Average tickets per trip [Ticket Type]	MCard Day = 1/3 Card Week=1/15 MCard Month=1/60 PnR= 1/2 Operator Single= 1 Operator Day = 1/3 Operator Week =1/15 Operator Month=1/60	tickets	Trips per ticket assuming 3 trips per work day (from WYCA) and 20 work days a month	Project Partners
Average time per use	1	Minute/use	Average time for travel apps such as Google Maps 45 sec, increased for ticketing purchases	[13]
Commission rate	3.5%	£/£	Commission rate between 5% for train market, and to 3%, 8% for international; Higher value assumed, based on rail market analysis	[18]
Contact rate	35	Persons/ month	The number of potential adopters with whom active adopters come into contact	[22]

Costs of ad-free version	3.99	£/person	equal to competitor app Traveline	Assumption
Cost of payment processing	2%	Dmnl	Retailers typically have to cover costs of electronic payment which can be between 0.5% and 3% of ticketing revenue plus any costs arising in case of fraud or refund claims.	[18]
Departure Information Weight	0.1	Dmnl	To get from survey data	Assumption
Engagement time other apps	24	Months	Based on assumed average	Assumption
Expected active users per sponsor	50,000	Persons/ sponsor	Hypothesis that the more active users there are, the higher the number of possible sponsors	Assumption
Expected monthly rewards per user	1	Rewards/ month/pe rson		Assumption
Fulfilment cost per ticket	0	£/ticket	These are charged for each electronic booking for tickets to cover costs of The rail industry charges £0.40 per ticket for collection from vending machines. Some costs assumed to still apply.	[18]
Further development costs	0	£	Estimate of costs for additional development	Project Partners
Initial active users other apps	10,000	persons	Based on users of rival MCard App on Google store	Google Store
Initial Bus share of bus-using population	24%		West Yorkshire 151,297,889.8 bus journeys a year NTS9903 = 15/16 Yorkshire & Humber 822 trips/person/year (excluding walk<1mile) 778k of WY population are in the high/medium segments and close to public transport.	[1,11]
Initial development costs	100,000	£	Assumed development costs based on project proposal; Development costs for ecommerce apps vary between $200k-$1mill, for On-demand apps between $100k-$1.5mill, for Two-sided market place apps $200k-$1.5mill.; Due to the complexity of integrating a variety of service products, costs are assumed to be at the higher end.	[23]

Lag time	3	Months		Assumption
Length of initial marketing campaign	3	Months		Assumption
Maximum addressable market	580,000	Persons	Total population potentially using the app	[1]
Maximum adoption fraction	1%	1/persons	Basic adoption fraction from literature = 1%, i.e. max 1% of contacted persons adopt the app	[22]
Maximum average engagement time	24	Months	Set to the simulation model run time; need to get real data on average engagement times and calibrate influence from user satisfaction	Assumption
Maximum bus share	0.26	Trips/Trips	Assumed less than 10% increase in bus share possible through app	Assumption
Maximum number of bus operators	10	operators	Actual number around 34, set to 10 for simplification; Market shares are constants, would have to be adapted if number were changed.	Project Partners
Month of further development	0	Month		Assumption
Monthly Cost of app implementation for bus operators	1,000	£/Operator/Month	CIVITAS II reported €10,000 spent for marketing, promotion, and training activities on a new ticketing system. Additional costs could arise from investment in software and potentially backoffice systems (€13,000 + €700k). CIVITAS II costs seemed to be mainly hardware related (vending machines).	[24]
Monthly Maintenance Costs/Active User	Look-up: 3000 rising to 5000 for 150k users	£/month		Project Partners
Monthly marketing cost rate	17,500	£/per campaign month	Estimated marketing costs per install (CPI) are \$1.2-\$1.6 depending on which markets are targeted and platforms used. Target installs are 20000 for three month campaign	[19]
Monthly rewards per sponsor and user	1	rewards/sponsors/Month/person		Assumption
Monthly Server Costs/Active User	Look-up: 150 rising to 3000 for 150k users	£/month		Project Partners
Monthly share increase	0.0001	1/month		Assumption

Months to spread costs	6	months		Assumption
Number of other apps	1	apps	Although many apps with similar functionality are available there	Assumption
Perceived quality of journal planner at release	1	Dmnl	To be refined from user survey	Assumption
Possible ad impressions per minute	2	impressions/ minute	Majority of ads are visible 30 sec Range has to been seen together with advertising fee	[16]
Proportion of app uses per trip	25%	uses/trips	Assumed to be only for trips where disruption is possible; according to the SMILE project, about 6% of users used their pilot app daily, and 30% several times per week.	Assumption
Quality of transport information	1	Dmnl	To be refined from user survey	Assumption
Satisfaction Car Hire	1	Dmnl	To be refined from user survey	Assumption
Share of active users per month	100%	1/months	Auxilliary variable for unit consistency	Assumption
Share of active sponsors per month	100%	1/months	Auxiliary variable for unit consistency	Assumption
Share of operators co-operating at start	0.1	Dmnl		Assumption
Share of ticket purchases using app	0.5	Dmnl	Dmnl	Project Partners
Share of users opting for ad-free version	5%	Dmnl	Set equivalent to share of users paying for in-app purchases	[15]
SWITCH: Ad-Free Apps	0	dmnl	1 = ON, 0 = OFF	n/a
SWITCH: Advertising	0	Dmnl	1 = ON, 0 = OFF	n/a
SWITCH: All Operators	1	Dmnl	1 = ON, 0 = OFF	n/a
SWITCH: Reward Function	0	Dmnl	1 = ON, 0 = OFF	n/a
SWITCH: Ticket Availability [Ticket Type]	MCard Day = 1 PnR = 1 All other MCard = 0	dmnl	1 = ON, 0 = OFF Only MCard Day and PnR available at present	n/a

	All single op = 0 * Share of operators co-operating			
Target quality of journey planner at end	1	Dmnl		Assumption
Technical cost rate	0	£/tickets	Third party retailers in the rail market are usually charged a small fee to access industry systems, e.g. to search for ticket options. Costs for accessing technical systems per ticket sale; 1% [Rowson, 2017]	[18]
Ticket Share [ticket Type]	[MCard Day]=0.014 [MCard Week]=0.075 [MCard Month]=0.075 [PnR]=0.006 [Operator Single]=0.2 [Operator Day]=0.2 [Operator Week]= 0.2 [Operator Month]=0.2			Project Partners
Ticket Weight	0.25	Dmnl	To be refined from user survey	Assumption
user satisfaction other apps	0.5	1/Apps	assume good planner and one other good function therefore achieves 0.5 out of possible 1	Assumption
Weight Additional Functionality	0.25	Dmnl	To be refined from user survey	Assumption
Weight Car Hire	0.1	Dmnl	To be refined from user survey	Assumption
Weight Journey planning function	0.25	Dmnl	To be refined from user survey	Assumption

Model Variables Equations

Parameter	**Unit**	**Equation**
Ad impressions per month	Impressions/month	=Possible ad impressions per minute*Average time per use*(1-"Share of users opting for ad-free version"

Additional App Functionality	Dmnl	= Disruption Information + Gamification + Saved Journeys + Taxi + Ticket Discounts + Train Tickets + Rewards
Additional bus trips per month	Trips/months	= average number of trips per month and person*(Bus mode share-Initial bus share for bususing population)*Active Users
Adoption Fraction	1/persons	= User satisfaction*Maximum Adoption Fraction/(user satisfaction other apps*number of other apps + User satisfaction)
Adoption from advertising	Persons/month	= Advertising impact rate*Potential Adopters
Adoption from word of mouth	Persons/month	= (Active Users*Word of mouth rate*Potential Adopters)/Total Population
Adoption rate	Persons/month	= Adoption from advertising + Adoption from word of mouth
Adoption rate other apps	Persons/month	= adoption word of mouth other apps
adoption word of mouth other apps	Persons/month	= (active users other apps*word of mouth rate others*Potential Adopters)/Total Population
Advertising impact rate	1/month	= If then else(Time<=Length of initial marketing campaign, Advertising effectiveness,0)
Advertising revenue	£/month	=Ad impressions per month*Advertising fee*"SWITCH: Advertising"
Agree to participate	Operators/Month	= If then else (Operators Cooperating<Maximum Number of Operators, If then else (Average expected monthly profit per operator>0, 1 ,0),0)
App Profitability	£/months	= Total monthly revenue to app provider-Cost of app operation-Marketing costs
App uses per month	uses/Month	= Average monthly app use per person*Active Users
Average engagement time	months	= max(0.033333*7,User satisfaction*Maximum average engagement time)
Average expected monthly profit per operator	£/(Month*Operators)	= (Monthly additional revenue from ticket sales + monthly revenue from ticket sales through app - Share of ticketing revenue) /Operators Cooperating - Monthly costs for app implementation per operator
Average monthly app use per person	uses/month/person	= average number of trips per month and person*Proportion of app uses per trip *User satisfaction
Average tickets per transaction[Ticket Type]	tickets	[MCard Day]= 1*MCard Day Share of Single Tickets+MCard Day Share of 3 Bundle Tickets*3+ MCard Day Share of 5 Bundle Tickets*5+MCard Day Share of 10 Bundle Tickets*10 [PnR]="P&R Share of Single Tickets"+5*"P&R Share of 5 Day Bundle"+10*"P&R Share of 10 Day Bundle" +20*"P&R Share of 20 Day Bundle" ALL OTHERS = 1
Cost of app operation	£/month	= cost of payment processing + cost of ticket fulfilment + Monthly customer support and maintenance costs +

		costs for accessing technical systems + Monthly Development Costs
Cost of payment processing	£/month	= Cost of payment processing rate*monthly revenue from ticket sales through app
Cost of ticket fulfilment	£/months	=Fulfilment cost per ticket*Total Monthly Ticket Transactions
costs for accessing technical systems	£/month	= Technical cost rate*Total Monthly Ticket Transactions
Earliest profit saving month	Month	=SAMPLE IF TRUE(:NOT:Earliest profit making month:AND:App profitability>0,Time,0)
Increase Bus share	Trips/Trips/Month	= If then else(User satisfaction>0.8, If then else(Bus mode share<Maximum bus share , Bus mode share*Monthly share increase, 0), 0)
Market share of operators co-operating	Dmnl	= WITH LOOKUP ((If then else("SWITCH: All Operators"=1 , 1 , Share of max operators)),([(0,0)-(1,1)],(0,0),(0.1,0.55),(0.2,0.8),(0.3,0.86),(0.4,0.9),(0.5,0.93) ,(0.6,0.95),(0.7,0.965),(0.8,0.98),(0.9,0.99), (1,1)))
Marketing costs	£/month	= If then else(Time<=Length of initial marketing campaign, Monthly marketing cost rate , 0)
MCard Day average price	£	= MCard Day Share of Single Tickets*MCard Day Single Price+MCard Day Bundle Price*(1-MCard Day Share of Single Tickets)
monthly additional revenue by ticket type[Ticket Type]	£/month	=Additional Bus trips per month*Average Ticket Price[Ticket Type]*Average Tickets per Trip [Ticket Type]
Monthly additional revenue from ticket sales	£/month	=SUM(monthly additional revenue by ticket type[Ticket Type!])
Monthly customer support and maintenance costs	£/months	="Monthly Maintenance Costs/Active Users"(Active Users) + "Monthly Server Costs/Active Users" (Active Users)
Monthly Development Costs	£/Month	=If then else(Time>=Month of further development:AND:Time<Month of further development +(Months to spread costs) , Further development costs/Months to spread costs , 0)
Monthly return	£/Month	App Profitability
Monthly revenue by ticket type[ticket type]	£/Month	=Average Ticket Price[Ticket Type]*tickets sold through app per month[Ticket Type]
monthly revenue from ticket sales through app	£/month	=SUM(monthly revenue by ticket type[Ticket Type!])
Monthly ticket transactions[ticket type]	Tickets/month	=tickets sold through app per month[Ticket Type]/Average Tickets per Transaction [Ticket Type]

Monthly trips using app Ticket [Ticket Type]	Month*trip	=tickets sold through app per month[Ticket Type]/Average Tickets per Trip[Ticket Type]
number of possible monthly rewards per user	rewards/Month/person	=Monthly rewards per sponsor and user*Reward Sponsors
P&R average price	£	="P&R Single Price"*"P&R Share of Single Tickets"+"P&R Bundle Price"*(1-"P&R Share of Single Tickets"
Perceived quality of journey planner	Dmnl	=(Target quality of journey planner at end-Perceived quality of journal planner at release)/FINAL TIME*Time+Perceived quality of journal planner at release
Perceived travel benefits	Dmnl	=Accessibility of offered modes*Accessibility Weight + Departure Information Weight*Quality of transport information + Satisfaction Car Hire*Weight Car Hire
Rate of loss of interest	Persons/months	= ZIDZ(Active Users,Average engagement time~~)~~
Rate of reconsidering	Persons/month	= Advertising impact rate*Users willing to reconsider+Active Users*Word of mouth rate *Users willing to reconsider /Total Population
Rate return to pool	Persons/month	= active users other apps/engagement time other apps
Recovery rate	Persons/month	= DELAY FIXED (Rate of loss of interest*User satisfaction, lag time, 0)
Revenue from ad-free app purchases	£/months	= Adoption Rate*"Share of users opting for ad-free version"*"Cost of ad-free version" *"SWITCH: Ad-free Apps
Reward satisfaction	Dmnl	=min(1,XIDZ(number of possible monthly rewards per user,Expected monthly rewards per user ,1))
Satisfaction with Ticketing availability	Dmnl	=SUM("SWITCH: Ticket Availability"[Ticket Type!]*Ticket Share[Ticket Type!])
Share of max operators	Operators/Operators	=INTEGER(Operators Cooperating)/Maximum Number of Operators
Share of ticketing revenue	£/Month	=Commission rate*monthly revenue from ticket sales through app
Sponsor attraction rate	sponsors/Month	=(INTEGER(Active Users*Share active users per month/Expected active users per sponsor -Reward Sponsors*Share active sponsors per month))*"SWITCH: Reward Function"
tickets sold through app per month[Ticket Type]	tickets/Month	=Active Users*average number of trips per month and person*Bus mode share*Share of ticket purchases using app*"SWITCH: Ticket Availability"[Ticket Type]*Ticket share[Ticket Type]*Average Tickets per Trip [Ticket Type]*Satisfaction with Ticketing availability
Total monthly revenue to app provider	£/Month	=Advertising revenue+Share of ticketing revenue+"Revenue from ad-free app purchases"

Total Monthly Ticket Transactions	Tickets/Month	= SUM(Monthly Ticket Transactions[Ticket Type!])
Total Monthly trips using app Ticket	Trip*month	=SUM(Monthly trips using app Ticket[Ticket Type!])
Total Population	persons	=If then else(Reduced Total Population switch=1,Bus mode share*Maximum addressable market,Maximum addressable market)
Total tickets sold	Tickets/month	= SUM(tickets sold through app per month[Ticket Type!])
User Satisfaction	Dmnl	=Perceived quality of journey planner*weight journey planning functionality+Perceived travel benefits+Satisfaction with Ticketing availability*Ticketing Weight+Additional App Functionality*Weight Additional Functionality
Word of mouth rate	1/month	= Adoption Fraction*Contact Rate
word of mouth rate others	1/month	= (Maximum Adoption Fraction-Adoption Fraction)*Contact Rate

Model Levels Equations

Parameter	Initial Value	Unit	Equation
Active users	0	persons	= INTEG (Adoption Rate + Rate of Reconsidering -Rate of loss of interest)
Active users other apps	initial active users other apps	persons	= INTEG (adoption rate other app-rate return to pool)
Bus mode share	Initial bus share for bususing population	Trips/trips	INTEG (Increase bus share)
Operators Co-operating	Share of operators cooperating at start*Maximum Number of Operators	Operators	= INTEG (agree to participate)
Potential adopters	Total population – Active users other apps	persons	= INTEG (-Adoption Rate-adoption rate other app+rate return to pool)
Registered inactive users	0	persons	= INTEG (Rate of loss of interest-Recovery rate)
Reward sponsors	0	sponsors	= INTEG (Sponsor attraction rate)
"Total return on investment (undiscounted)"	-Initial development costs	£	= INTEG (Monthly return)
Users willing to reconsider	0	persons	= INTEG (Recovery rate-Rate of Reconsidering)

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