B.Tech. Project

on

Mobility as a Service

Project code: P&I 10

Submitted by

Arundhati Dixit (Entry No: 2016ME10824)

Rohit Kumar Singh (Entry No: 2016ME10080)

Supervised by Professor Nomesh Bolia

Mechanical Engineering Department

Indian Institute of Technology Delhi

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Abstract

In order to tap into a much larger market, combat with the sluggish growth in the automobile industry, and present flexible pricing for revenue management, Mobility as a Service (MaaS) is an innovative transport concept, anticipated to induce significant changes in the current transport practices. However, there is ambiguity surrounding the concept; it is uncertain what are the core characteristics of MaaS and in which way they can be addressed. Further, there is a lack of an assessment framework to classify their unique characteristics in a systematic manner, even though several MaaS schemes have been implemented around the world. In this study, we define this set of attributes through a literature review and survey, which is then used to describe selected MaaS schemes and existing applications. We also examine the potential implications of the identified core characteristics of the service on the following three areas of transport practices: travel demand modelling, customer preference study and business model design. Finally, we propose the necessary steps needed to deliver such an innovative service like MaaS, by establishing the state of the art in those fields.. The prospects of marketing cars as a service, and not commodity are tremendous, and will only increase with the advent of automation. This model can incorporate past clientele, work for increased services for the present users, and create a sustainable development model for future users in the benefit of environment. For the use of a car, a consumer can either permanently secure it (buying it), or attach a small recurring cost with its usage (renting it). The choice from the buyer's perspective is to minimise the total operational cost, and from seller's perspective is to maximise revenue. We have to look at some existing MaaS models or models similar to this concept from all over the world, compare total costs from buyer and seller perspective, and finally incorporate services such as insurance, maintenance, fuel and time frame of offers to design subscription plans for the same.

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1

Introduction

1.1 | Background

Automobiles, since conception, have redefined the way people move. A step further in this field would be to market vehicles as services. For designing a business plan for the same, the steps for study would be to identify existing structures in the automobile market, estimate customer preference, demand and willingness to pay, pinning constraints based on prior study and cost to company, maximising revenue, and standardising the model. Sharing economy firms are disrupting traditional industries across the globe. For proof, look no further than Airbnb which, at $10 billion, can boast a higher valuation than the Hyatt hotel chain. Uber is currently valued at $18.2 billion relative to Hertz at $12.5 billion and Avis at $5.2 billion. Beyond individual firms, there are now more than 1,000 cities across four continents where people can share cars. The global sharing economy market was valued at $26 billion in 2013 and some predict it will grow to become a $110 billion revenue market in the coming years, making it larger than the U.S. chain restaurant industry. The revenue flowing through the sharing economy directly into people's wallets will surpass $3.5 billion this year, with growth exceeding 25%, according to Forbes. The business model– where peers can offer and purchase goods and services from each other through an online platform – continues to be applied to new industries from car sharing to peer-to-peer fashion, among many others. These firms bring significant economic, environmental, and entrepreneurial benefits including an increase in employment and a reduction in carbon dioxide emissions (in the case of car sharing services). Shervin Pishevar, a venture capitalist and an investor in Couchsurfing, Getaround, Uber and other startups in this space, believes these services will have a major impact on the economics of cities; "This is a movement as important as when the web browser came out."

1.2 | Introduction to the problem being addressed in the project

Figure 1.1: Need for redefining the automobile landscape

Automobile is a multi billion industry with more than 20 million automobiles sold every year. With decline in vehicle sales by 18.71% this fiscal year in India and a very slow growth rate of 5.81% over the past years, this land of missed opportunities has prompted us to develop an alternative arrangement of providing mobility solutions as a service rather than commodity.
Mobility as a Service can be developed as a self sufficient and well equipped ecosystem, encompassing the needs of all members of the society, in addition to boosting sustainable solution for daily needs

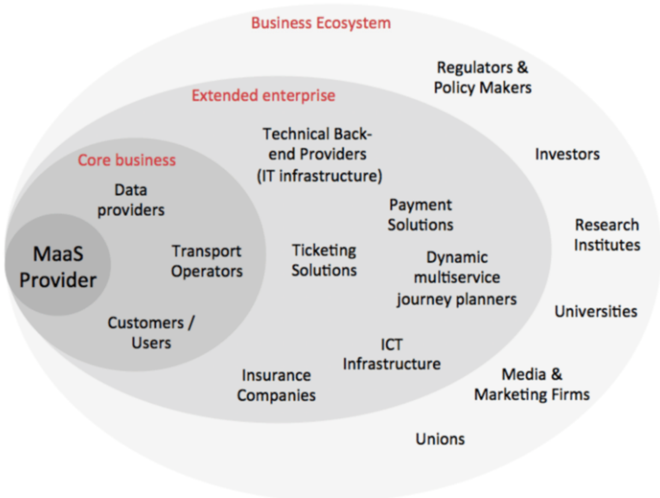


Figure 1.2: The MaaS ecosystem

1.3 | Overview of the thesis

In recent years, the increasing number of transport services offered in cities and the advancements in technology and ICT have introduced an innovative Mobility as a Service (MaaS) concept. It combines basic transport mode services to offer a tailored mobility package, similar to a monthly mobile phone contract and includes other complementary services, such as trip planning, reservation, and payments, through a single interface. This bundling of mobility modes and services presents a shift away from the existing ownership-based transport system toward an access-based one. It offers users a hyper-convenient mobility solution, with a promising perspective to substitute private car. Given its promising prospects, there is still a high degree of ambiguity surrounding the concept with multiple sources vying to offer definitions of MaaS, many of which may conflict with one another or deal with different aspects of the concept altogether. Additionally, although several MaaS schemes have been implemented around the world, there is a lack of assessment framework that classifies their unique characteristics in a systematic manner. “What constitutes a MaaS concept?” is the central proposition of this study. To examine this proposition, we first attempt to define MaaS and the core characteristics based on a literature review. Next, we use this review to characterise the expectations from a business model under the purview of MaaS. This reveals certain differences and similarity trends among the studies considered. It also grounds our theoretical characteristics of MaaS at an operational level and reveals certain attributes unique to a practical level. Next, we highlight the challenges to approach this emerging phenomenon of MaaS, by examining the potential implications of the identified core characteristics of the service on the following three areas of transport practices: travel demand modelling, customer preference study, and designing business model. We review the state of the art in the three areas and explore the probable enhancements that will be required to deliver such an innovative and integrated mobility service. Finally, the paper is concluded in chapter x. The outcomes can be useful to pinpoint MaaS’ core characteristics, derive a framework to assess MaaS schemes that fulfil to a certain degree this set of attributes and to indicate future challenges in transportation research.

2

Literature Survey

2.1 | The Concept

Mobility as a Service (MaaS) is a very recent mobility concept. It can be thought of as a concept (a new idea for conceiving mobility), a phenomenon (occurring with the emergence of new behaviours and technologies) or as a new transport solution (which merges the different available transport modes and mobility services).

- The first **comprehensive definition of MaaS** is offered by Hietanen (2014). He describes MaaS as a mobility distribution model that delivers users' transport needs through a single interface of a service provider. It combines different transport modes to offer a tailored mobility package, like a monthly mobile phone contract. This interpretation encompasses some of the core characteristics of MaaS: customer's need-based, service bundling, co-operativity and inter-connectivity in transport modes and service providers.

- Cox (2015) adds to this definition, by emphasizing the similarity with the telecommunication sector. Being based on the same definition, Finger, Bert and Kupfer (2015) envisioned MaaS to integrate transport modes through the internet. Holmberg, Collado, Sarasini and Williander (2016) emphasized the **role of subscription** in MaaS, giving the user the possibility to plan his/her journey, in terms of booking and paying the several transport modes that might be required, all in one service. Based on the traveller's needs, he/she can have the choice of 'pay-as-you-go' or pre/post pay, considering his/her registration and a monthly subscription. At a second stage, subscription results in **personalisation**, framing mobility services around traveller's preferences, which is one important advantage that is absent from conventional public transport services and thus not covering passenger's needs which might result in inconvenience (Atasoy, Ikeda, Song, and Ben-Akiva, 2015). More specifically, tailoring the bundles to the heterogeneous needs of the subscribers (i.e. preferences in mode choice) is beneficial for both users and transport providers usually referred to as collaborative customisation or personalisation (Hietanen, 2014; Kamargianni, Matyas, Li, and Schäfer, 2015).

- In addition to the definitions above, which emphasize the bundling and subscription aspects of MaaS, there are various other interpretations of the term that underscore other aspects. Atkins (2015) defines MaaS as a mobility service that is flexible, personalized and on-demand. Evidently, MaaS essential characteristic is the user-centric vision which frames the mobility service provision, a view which many authors strongly emphasize. The key function of the internet and, more in general, of the technologies, has also been underlined in several definitions. Nemtanu, Schlingensiepen, Buretea and Iordache (2016) consider the **Information and Communication Technologies** (ICTs) as the main component of MaaS systems. They mention the collection, transmission, process, and presentation of the information necessary for identifying the best transport solution for user's needs. The emergent notion in the **Internet of Things** (IoT), which further accentuate the connectivity between physical objects and virtual data, is a vision of Smart transportation systems to support the Smart City vision (Sherly Somasundareswari, 2015).

- By providing seamless travels with accessible and affordable solutions, MaaS has a perspective to contribute toward the strategic goals to achieve integrated multimodal systems, substituting private vehicles with alternative models (Chowdhury and Ceder, 2016; CIVITAS, 2016; Luk and Olszewski, 2003). Gould, Wehrmeyer and Leach (2015) envision MaaS as an opportunity to **decarbonise transport** sector by reducing the use of private cars and encouraging the diffusion of electric vehicles (EVs) within the city.

- Based on the aforementioned definition and prior work in the field (Doganova Eyquem- Renault, 2009), Boons and Lüdeke-Freund (2013) established a framework of BMfSs, consisting of four business model building blocks: a value proposition, supply chain, customer interface, and financial model. Their operationalization of the four elements of a BMfS is provided below (Boons Lüdeke-Freund, 2013, p. 45):
  - Value proposition: provides measureable ecological and/or social value in concert with economic value

- Supply chain: involves suppliers who take responsibility toward their own as well as the focal company's stakeholders
- Customer interface: motivates customers to take responsibility for their consumption as well as for the focal company's stakeholders
- Financial model: reflects an appropriate distribution of economic costs and benefits among actors involved in the business model and accounts for the company's ecological and social impacts

- Interestingly, Giesecke et al. (2016) conceptualize MaaS as a **socio-technical phenomenon** with sustainability as a critical aspect, thus shedding the light on the sociological level and the sustainability dimensions of the concept.

- In the interpretation of König, Eckhardt, Aapaoja, Sochor and Karlsson (2016), MaaS offers need-based and customized mobility solutions for the users with the goal of achieving a more **sustainable transport**. This change of focus considers the social context to fulfil users' needs and environmental aspect while addressing the challenge of urban mobility.

Other definitions considered the user-centred perspective from an operational point of view (Ghanbari, Álvarez San-Jaime, Casey, Markendahl, 2015; Kamar- gianni et al., 2016; Rantasila, 2016). The main goal of MaaS systems is to provide seamless door-to-door mobility for users. This is made feasible by the technological advances, the cooperation of different operators, the bundling of several transport modes. Things have to be done in a smarter and more efficient way and by the full deployment of ICT and a stronger cooperation between public and private transport providers, Maas can result in a better allocation of resources and services, with the citizen as an end-user (Hietanen, 2014).

2.2 | Car Sharing Business Models for Sustainability

Table 2A

Segment	Value proposition	Supply chain	Customer interface	Financial model	Examples
B2C point to point	Reduces emissions and congestion	OEM vehicles; some programs using EVs and hybrids	Shift from vehicle acquisition to shared use	More affordable access to a vehicle than owning and maintaining	Car 2 Go
	A vehicle when you want/need one and no requirement to return to same location			Potential for profitability and exit	
B2C roundtrip	Reduces emissions and congestion	OEM vehicles; some programs using EVs and hybrids	Shift from vehicle acquisition to shared use	More affordable access to a vehicle than owning and maintaining	Zipcar
	A vehicle when you want/need one			Potential for profitability and exit	
Nonprofit/cooperative	Reduces emissions and congestion	OEM vehicles; some programs using EVs and hybrids	Shift from vehicle acquisition to shared use	More affordable access to a vehicle than owning and maintaining	Modo
	A vehicle when you want/need one			Member revenue, sponsorship, government subsidies/grants	
P2P	Reduces emissions and congestion	P2P models are unique in that they require virtually no additional production or suppliers; instead P2P firms serve as intermediaries between owners and renters; that is, generally more environmentally sustainable than B2C models	P2P models encourage vehicle owners to share a resource	Provides additional income to vehicle owners to offset the high cost of ownership	Relay Rides
	A vehicle when you want/need one and no requirement to return to same location		For the renter it also shifts from acquisition to shared use	For renters it provides more affordable access to a vehicle for than owning and maintaining a personal vehicle	Flight Car
	Usually more variety of vehicle types for renters			Scalable revenue model based on a percentage of transaction without need to acquire vehicles	
	For the owner, a way to generate extra income from a subutilized resource				

Note: EV = electric vehicle; OEM = original equipment manufacturer; B2C = business to consumer; P2P = peer-to-peer

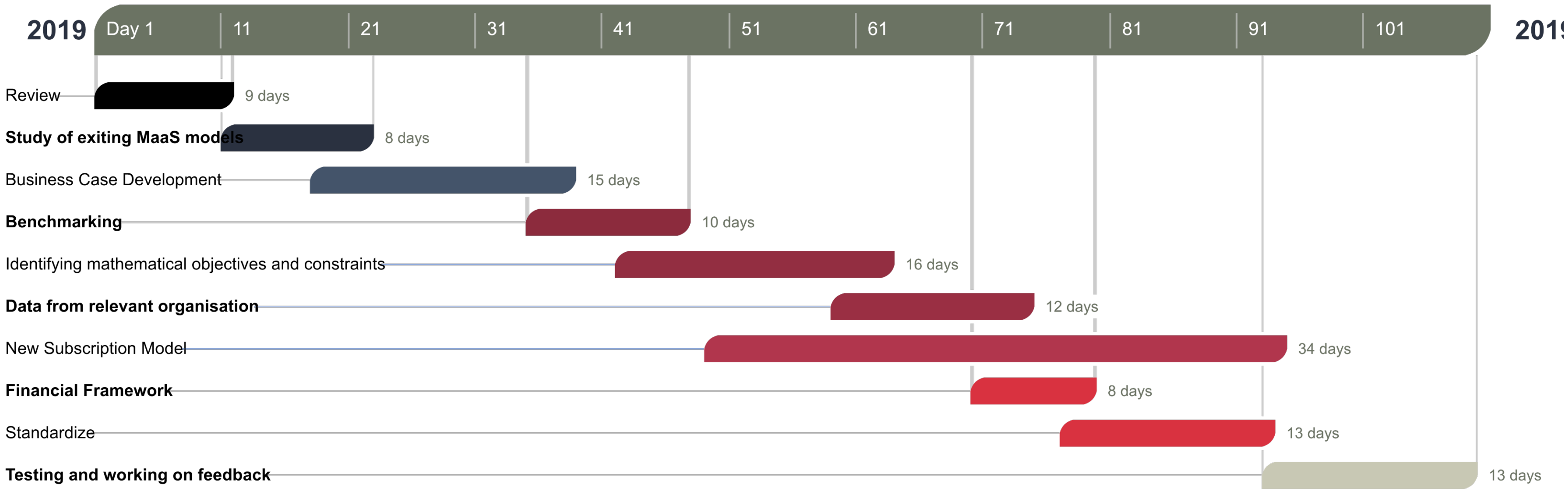
3

Project Objectives and Work Plan

3.1 | Aim

- To identify the market and demand for automobile industry
- Consider company's objectives, constraints, obstacles and feedback for model
- Identify services to be included rigidly/flexibly
- Stipulate a time frame for subscription
- Maximize revenue subject to customer's willingness to pay
- Minimize cost to company for operation
- Design optimal allocation for different classes of customers for subscription
- Make it adaptable to current operations, and standardize the model for operation in cities

3.2 | Work Plan


2019
Day 1
11
21
31
41
51
61
71
81
91
101
2019
Review
9 days
Study of exiting MaaS models
8 days
Business Case Development
15 days
Benchmarking
10 days
Identifying mathematical objectives and constraints
16 days
Data from relevant organisation
12 days
New Subscription Model
34 days
Financial Framework
8 days
Standardize
13 days
Testing and working on feedback
13 days

4

Market Study

4.1 | Total Cost to Company

By looking at market models, modelling of **Total Cost to Company (TCO)** can be done for cars, which would be a primary constraint while designing subscription models. Total cost is an estimate of the total cost to own a car for a five year period. It includes all the expenses spent on services like fuel, insurance, maintenance, repairs, service, interest on loan payments as well as the losses incurred due to depreciation of the car at the end of the same period. It is calculated assuming 10% down payment on car finance at 12% APR for a 5 year loan term.

Figure 4.1: Cost to Company for a car

4.2 | Comparing Renting and Buying

Revv is a company that allows for renting a car for variable periods of time. We compare cost to rent a car with TCO (Total Cost of Ownership) to estimate whether it is optimal to rent a car, or to buy one for multiple car models. Evidently, cost of renting the car on Revv is much higher, so the customer will choose to buy the car anyway. Moreover, this company doesn't cover maintenance and rent. If we look at a car owner of medium usage, then renting is more expensive. But the gap between renting and buying decreases. Thus, a rational customer will go for buying a car. It is also easy to notice that the gap is not uniform for different models of cars, which is unexplained. This is also not a feasible option for any user. For high usage, gap between renting and buying further reduces, but it still isn't the logically optimal option, since customer's willingness to pay will be the maxima of price of current available services. So unless this gap is bridged, renting will not be a feasible option, let alone competitive.

The following tables and and graphs indicate the differences as existent in the market.

Table 4A: Low Usage

Model	% difference
Maruti Suzuki VXI	11.48
Hyundai Tucson 2WD MT Diesel	40.48
Maruti Ciaz Delta 1.3	61.77
Nisan Micra XV DSL	90.72

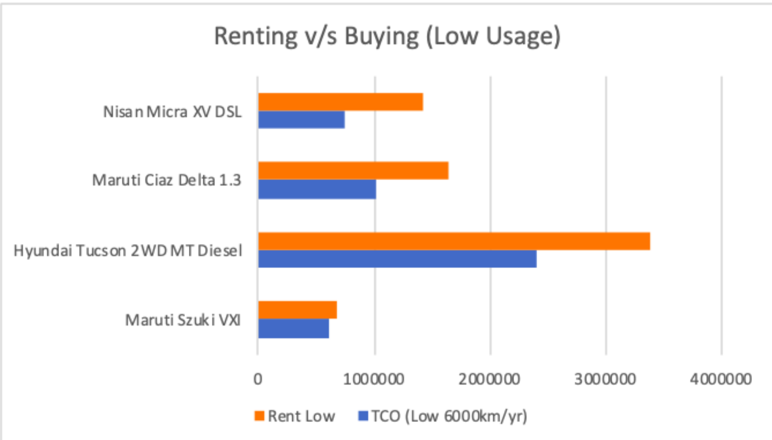


Table 4B: Medium Usage

Model	% difference
Maruti Suzuki VXI	36.78
Hyundai Tucson 2WD MT Diesel	29.75
Maruti Ciaz Delta 1.3	40.95
Nisan Micra XV DSL	64.95

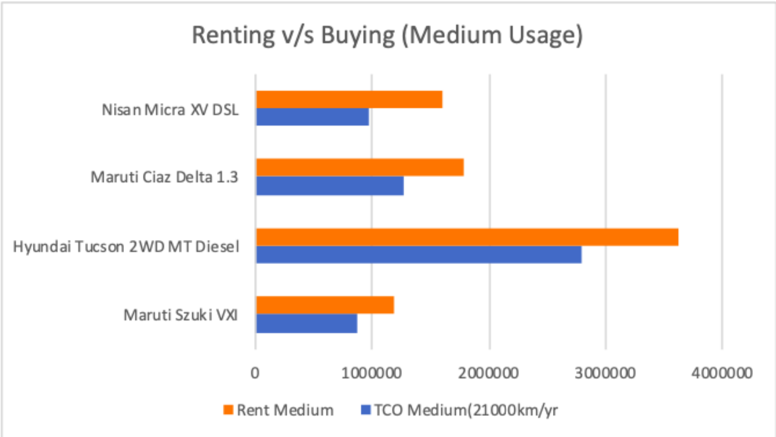
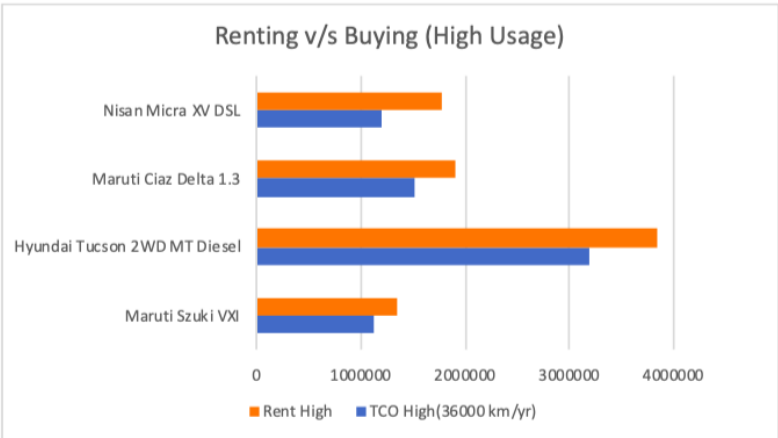


Table 4C: High Usage

Model	% difference
Maruti Suzuki VXI	18.58
Hyundai Tucson 2WD MT Diesel	20.00
Maruti Ciaz Delta 1.3	25.65
Nisan Micra XV DSL	48.71



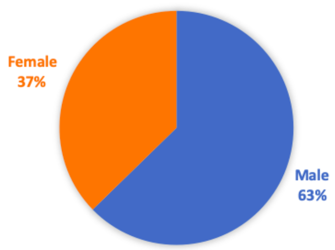
Renting is not viable in the industry, but present models help us gauge cost to company and customer base. Further, studying the bundles and plans offered by these companies help us understand the possibilities, customer preferences and more scope for revenue generation.
In designing subscription in our project, we have kept these things in mind. In addition, we have asked the customers to indicate their preferences instead of choosing between plans because plans offered right now are not feasible.
A thing to be done in this matter is to actually study the pricing model of a company like Revv, and we intend to do so, given the opportunity.

5 Surveying Potential Market

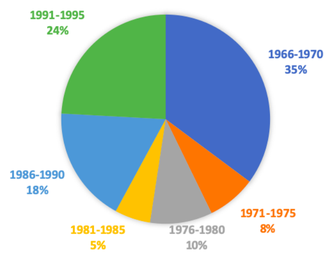
5.1 | Overview of the Responses

Number of respondents = 145

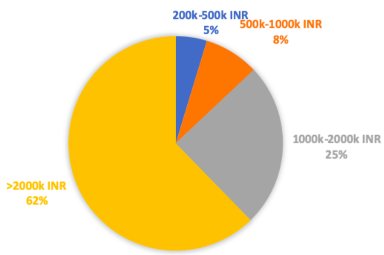
5.1.1 | Customer Profile



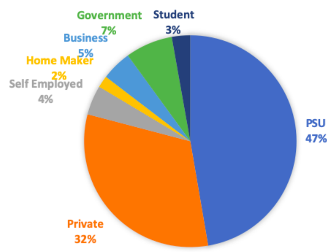
(a) Gender



(b) Year of Birth

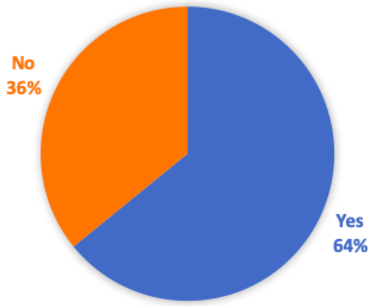


(a) Income per Year

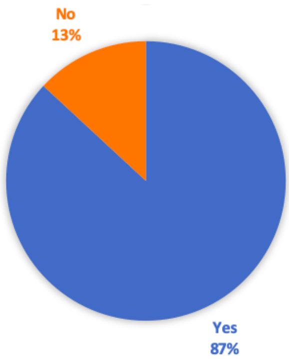


(b) Sector of Employment

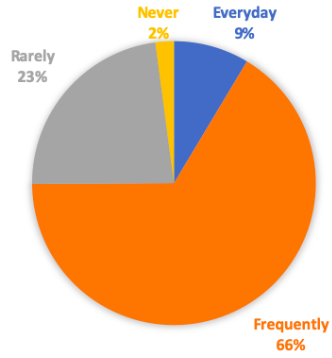
5.1.2 | Travel Pattern



(a) Car Ownership

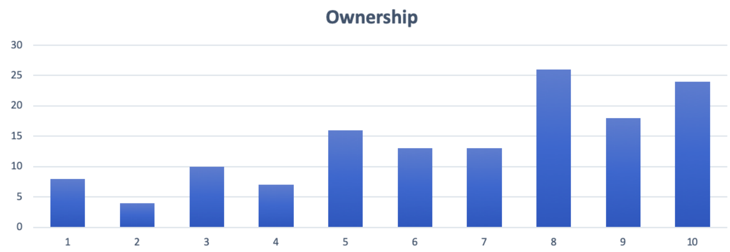


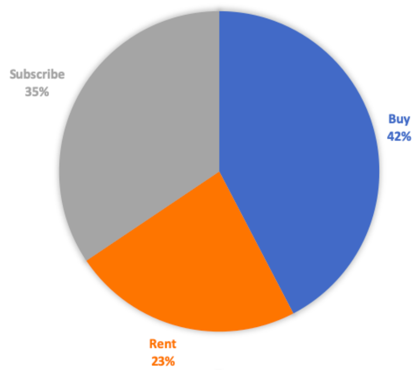
(b) Driving License Ownership



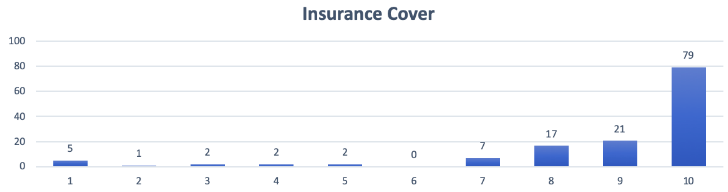
(c) Use of car rentals such as Ola/Uber/other taxis

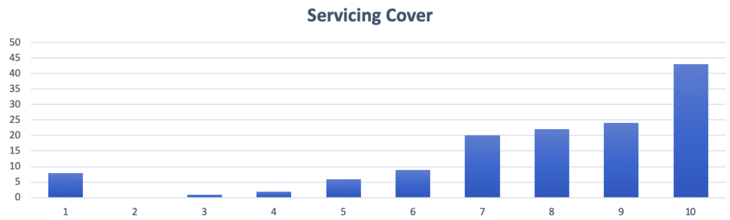
5.1.3 | Ownership and choice of mobility solution

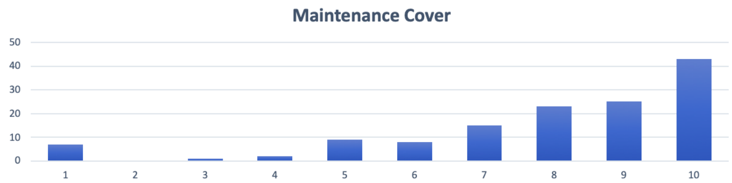


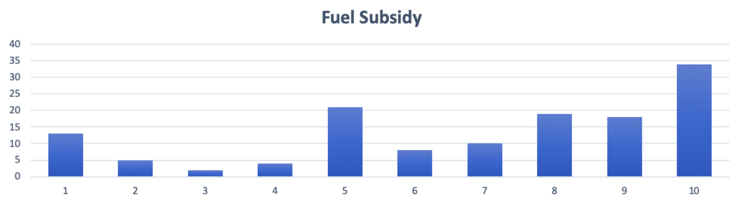


5.1.4 | Rating Importance of Services









5.2 | Modelling the Problem

The empirical analysis of bundle choice applies the random utility framework. In these models, the utility is decomposed into two additively separable parts, a deterministic component which is a function of measured attributes and a stochastic error component representing unobserved attributes affecting choice. The most commonly used family of models is the logit (MNL) model, which due to its IID properties assumes constant variances and zero covariances. However, the restrictive characteristics of this model do not take into account the repeated nature of SP data that result in each respondent being recorded in multiple-choice situations. This means, that there are unobserved effects which remain constant within an individual between replications leading to correlations among these observations. To account for this panel/agent effect we follow a Mixed MNL model with random coefficients specification. This allows tastes to be constant across replications for the same respondent (intrarespondent taste homogeneity) but with variation in tastes across respondents. The resulting utility, U_int, that decision maker n receives from alternative i in choice situation t is assumed to be:

$$U_{int} = V_{int} + \alpha_{in} + \epsilon_{int}, i\epsilon C_{nt}$$

where the term α_{in}. corresponds to an additional additive common error term, which represents random taste variation across individuals. We assume ϵ_{in} is normally distributed with a zero mean and σ_panel standard deviation. σ_panel becomes an additional parameter to be estimated. Following the MMNL framework, the systematic utility functions for modelling MaaS plan choice are now defined as:

$$V_{Plan1} = \beta' X_{1n} + \alpha_{panel}$$

$$V_{Plan2} = \beta' X_{2n} + \alpha_{panel}$$

$$V_{Plan3} = \beta' X_{3n}$$

The three plans can refer to Pay as you go, 1 month subscription, and six month subscription. It can also be adjusted to different packages which include different service bundles. β' are vectors of unknown parameters and X_in are vectors of observed attributes of in each plan, which in our model are the modes included in the plans. The individual-specific error terms were added to only other alternatives as we need to normalize one. We have used this model to initially simply predict whether the customer will **buy a car, rent a car or subscribe for a car**. Further, we want to use it on specific packages.

Table 5A

Characteristic	Coefficient	t-test
Year of Birth-dummy	-0.022	-1.95*
Gender-dummy	0.056	1.66
Income per year	-0.069	-12.18***
Use of car rentals-dummy	0.517	6.61***
Car ownership-dummy	0.299	1.70
Travelled distance in a day-continuous	0.253	6.51***
Importance of ownership	-0.356	-2.00**
Plan cost	0.411	-9.15***
σ_{panel}	0.758	9.46***
Sample size: 145		
Initial log likelihood: 41400.67		
Final log likelihood: 33840.36		
Likelihood ratio test for the initial model: 15120.61		
R^2 = 0.483		

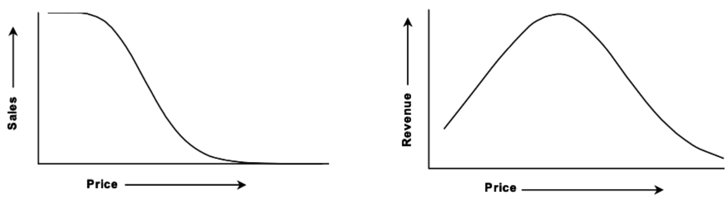
Turning to the plan characteristics, as presumed, the cost coefficient is negative and statistically significant at the 99% confidence level. This means that as plans become more expensive, people prefer them less. Regarding travel patterns in the plan, all of them are statistically significant. This shows that the type and amount of transport modes in the plans are important to users and should be carefully considered in the design of plans. It also helps us identify the set of potential audience.

Further, we regressed the parameters on scores provided by customers to different services. Given a customer profile, we want to predict whether or not to include a particular service in package. We include the service if the predicted score is higher than a threshold, and if the predicted score is lower, the service is not included.
Since the data points were inadequate for this analysis and we could not figure out how to predict a threshold, we will take this part of the work up in the next semester if given the opportunity, when we will potentially have more insight. Also, in tailoring a package, we would like to consider the company view more thoroughly which we intend to do in the upcoming months.

6

Willingness to Pay

A company needs to balance volume (coverage) and revenue (sustainability). The law of demand says that we cannot get both coverage and sustainability at the same time — as prices go up, demand will come down. Client loss with increasing prices is inevitable, except in those cases where starting prices are so low or demand is so high that demand is insensitive to price changes. Willingness to pay (WTP) surveys allow us to simulate price-related changes in demand without actually changing prices, giving them a way to make pricing decisions based on empirical information.



(a) Price and Sales (b) Price and Revenue

Figure 6.1: General Relationships

6.1 | Why a Survey

- The survey methodology is simple and unobtrusive to apply, and the direct estimation techniques can be applied by any research unit.
- WTP techniques can be used for both existing products and services and new goods that are not yet available in the market. Depending on the program context

and decisions to be made, the survey can be administered to either population-based or facility-based samples.

- Even customers without formal education can answer hypothetical price questions, and their answers are usually internally consistent.
- WTP estimates are sensitive to client characteristics, such as motivation to use the product or service, or socioeconomic status (SES).
- Direct WTP estimates are conservative; that is, they underestimate maximum WTP and protect companies from raising prices too high.

This said, however, two additional notes are in order:

1. The hypothetical price range to be tested is determined prior to applying the full-scale WTP survey. Target prices are based on programmatically relevant information, such as program costs to deliver the service or product, program needs for additional revenue to meet rising costs or to cross-subsidize other activities, prices at competing outlets, etc.
2. Further study is needed to validate the results of decision making based on WTP surveys.Additional field experiments are needed to assess the accuracy and sensitivity of WTP-derived estimates use.

6.2 | WTP Survey

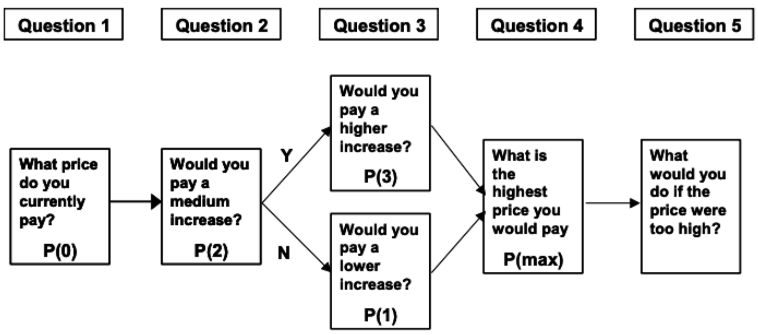


Figure 6.2: Flow of Questions

Above figure illustrates the order of questions applied to respondents who are currently using the product or service. Literature suggests that users and prospective users

in developing countries often treat the WTP questions as a bargaining situation. They are more willing to pay a given price when it is the low price increment than when it is the medium price increment (first price asked) or the highest price increment.
Aligning with the model assumptions, two cautionary points are included in the survey:

1. Assume that your income will stay the same even if the agency prices change.

2. Alternatives do exist for the agency services (i.e. other taxi service, availing you company car service, car pooling etc).

The direct analysis procedure outlined above will tend to underestimate maximum WTP because only a few price probes are asked, and many respondents may simply repeat the highest probe accepted as the maximum price they are willing to pay.

6.3 | Calculating WTP

6.3.1 | Direct estimation method for calculating the demand curve

We surveyed 145 people who work in different companies in Gurgaon an New Delhi, (mostly our parents' workplaces) for the purpose of resolution of WTP. We used the price of subscribing for Hyundai i10.

Table 6A

Value (INR)	Frequency	Percentage	Cumulative
30,000	1	0.714	92.143
25,000	5	3.571	91.428
22,000	9	6.428	87.85714286
21,000	18	12.857	81.42857143
20,000	26	18.571	68.57142857
18,000	25	17.857	50
15,000	22	15.714	32.14285714
10,000	18	12.857	16.42857143
5,000	5	3.571	3.571428571

Out of the 145 responses, 92.143% of the people responded to the question on maximum willingness to pay and price change question satisfactorily. Frequency of each response has been listed in the given table, and we can plot it to obtain the expected percentage of customers who accept a price. We plot the complement of cumulative percentage against Maximum WTP.

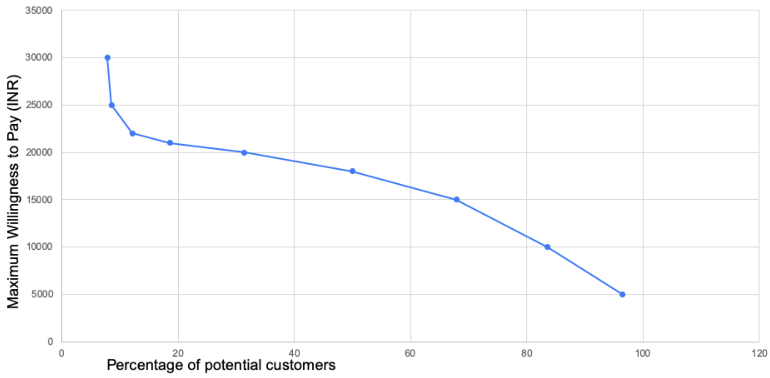


Figure 6.3: Consumer Price vs Demand curve from survey

6.3.2 | Estimating Demand at Socio-Economic Status

This analysis would be more useful if the number of data points were higher, the the data in totality was more representative. In order to have a better picture, we have split the customers into two classes: Income > 2000000 INR and Income < 2000000 INR. The difference in WTP is quite clear, as illustrated in the graph.
This gap illustrates potential for capturing revenue based on customer profile.

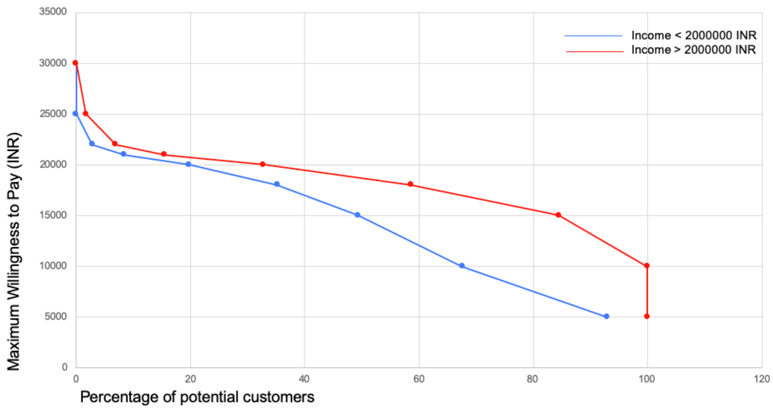


Figure 6.4: Consumer Price vs Demand curve differentiated on Socio-Economic Status

This can be further done on customer travel patterns, but since we do not have adequately representative data, we have limited our analysis in this scope.

7

Capacity Control

7.1 | Static Model

7.1.1 | Two Class Model

The model assumes two product classes (class 1 : Subscribe to a model, class 2: Pay as you go), with associated prices $p_1 \geq p_2$. The capacity is C, and we assume there are no cancellations or overbooking. Demand for class j is denoted by D_j and its distribution is denoted by $F_j(.)$. Demand for class 2 arrives first. The problem is to decide how much class 2 demand to accept before seeing the realization of class 1 demand.
Suppose that we have x units of capacity remaining and we receive a request from class 2. If we accept the request, we collect revenues of p_2. If we do not accept it, we will sell x units (the marginal unit) at p_1, if and only if demand for class 1 is or higher. That is, if and only if $D_1 \geq x$. Thus, the expected gain from reserving x^{th} unit for class 1 (the expected marginal value) is $p_1 P(D_1 \geq x)$. Therefore, it makes sense to accept a class 2 request as long as its price exceeds this marginal value, or equivalently, if and only if

$$p_2 \geq p_1 P(D_1 \geq x) \tag{7.1}$$

Therefore, the optimal protection level (an amount of capacity to reserve for class 1, denoted by y_1^*) such that we accept class 2 if th remaining capacity exceeds y_1^* and reject it if the remaining capacity is less than or equal to y_1^*. Formally y_1^* satisfies

$$p_2 < p_1 P(D_1 \geq y_1^*) and p_2 \geq p_1 P(D_1 \geq y_1^* + 1)$$

If a continuous distribution of $F_1(x)$ is used to model the demand, then the optimal protection level y_1^* can be given by:

$$y_1^* = F_1^{-1}(1 - \frac{p_2}{p_1}) \tag{7.2}$$

7.1.2 | n-Class Model

We assume that demand for the n classes arrives in stages, one for each class, with classes arriving in increasing order of their revenue values. Let the classes be indexed so that $p_1 > p_2 > ... > p_n$ Hence, class n (the lowest price) demand arrives in the first stage (stage n), followed by class $n-1$ demand in stage $n-1$, and so on, with the highest price class (class 1) arriving in the last stage (stage 1). Hence there is one to one correspondence between stages and classes, thus we index both by j. For the sake of simplicity Demand and capacity is assumes discrete in this model.

Dynamic Programming Formulation This problem can be formulated as a dynamic program in the stages (equivalently, classes), with the remaining capacity x being the state variable. At the start of each stage j the demand $D_j, D_{j-1}, ..., D_1$ has not been realized. Within stage j the model assumes that the following sequence of events occurs

1. The realization of the demand D_j occurs and we observe its value.
2. We decide on a quantity u of this demand to accept. The amount accepted must be less than the capacity x remaining, so $u \leq x$. The optimal control u^* is therefore a function of the stage j, the capacity x, and the demand D_j.
3. The revenue $p_j u$ is collected, and we proceed to stage $j-1$ with capacity $x-u$.

Now let $V_j(x)$ denote the value function at the start of stage j. Once D_j is observed, the value of u is chosen to maximize the current stage j revenue plus the revenue to go

$$p_j u + V_{j-1}(x-u)$$

subject to the constraint $0 \leq u \leq \min\{D_j, x\}$. The value function at stage j is:

$$V_j(x) = E\left[\max_{0 \leq u \leq \min\{D_j, x\}} \{p_j u + V_{j-1}(x-u)\}\right] \tag{7.3}$$

with boundary conditions $V_0(x) = 0 \quad \forall x \in \{0, 1 \ldots, C\}$ solving the above yields:

$$y_j^* = \max\{x : p_{j+1} < V_j(x) - V_j(x-1)\}, \quad j = 1, \ldots, n-1 \tag{7.4}$$

7.2 | Dynamic Model

7.2.1 | Formulation Without Replacement

We assume n classes with prices $p_1 \geq p_2 \geq \cdots \geq p_n$. There are total T periods and t indexes the periods, with the time index running forward($t = 1$ is the first period and $t = T$ is the last period). j indexes the classes.

In each period we assume that at most one arrival occurs. This can be achieved by sufficiently discretization of time.

$$\sum_{j=1}^{n} \lambda_j(t) \leq 1$$

Dynamic Program Let $V_t(x)$ denote the value function in period t, Let $R(t)$ be a random variable, with $R(t) = p_j$ if a demand for class$j$ arrives in period t and 0 otherwise. Thus we have $P(R(t) = p_j) = \lambda_j(t)$. Also let $u = 1$ (control variable) if we accept the arrival 0 otherwise. Hence objective is to maximize the sum of current revenue and revenue to go, i.e.

$$R(t)u + V_{t+1}(x-u)$$

Hence the Bellman equation is

$$V_t(x) = E\left[\max_{u\in\{0,1\}} \{R(t)u + V_{t+1}(x-u)\}\right] \tag{7.5}$$

with following boundary condition

$$V_{T+1}(x) = 0 \quad x = 0, 1 \ldots, C$$

and

$$V_t(0) = 0 \quad t = 1 \ldots, T$$

This is due to the fact at any units left unsold after the deadline will not be worth anything and if we have zero inventory we can't do anything.

7.2.2 | Formulation with Replacement

We model this as a finite horizon Markov Decision Process (MDP). The MDP is specified by:

States ($s =< t, x, u >$) : Here x is the capacity of cars in period t and u is the capacity which will be replenished at the end of period t (will be available before the start of next period)

Action A : Available from each the states. These actions will be to do nothing (coded 0), to rent out car in pay as you go fashion(coded 1) during period t only and to give it to customer for subscription(coded 2) for extended period T thereafter it will be available again

Transition Probability $\Gamma(s, a, s')$: Defined as a probability that an action a taken from state s leads to s'.

Reward $R(s, a, s')$:Reward which we get for taking action a from state s which leads to s'

Discount Factor γ : A real number between $(0, 1]$. This factor is to ensure that subsequent states effects the reward of the current state in discounted fashion

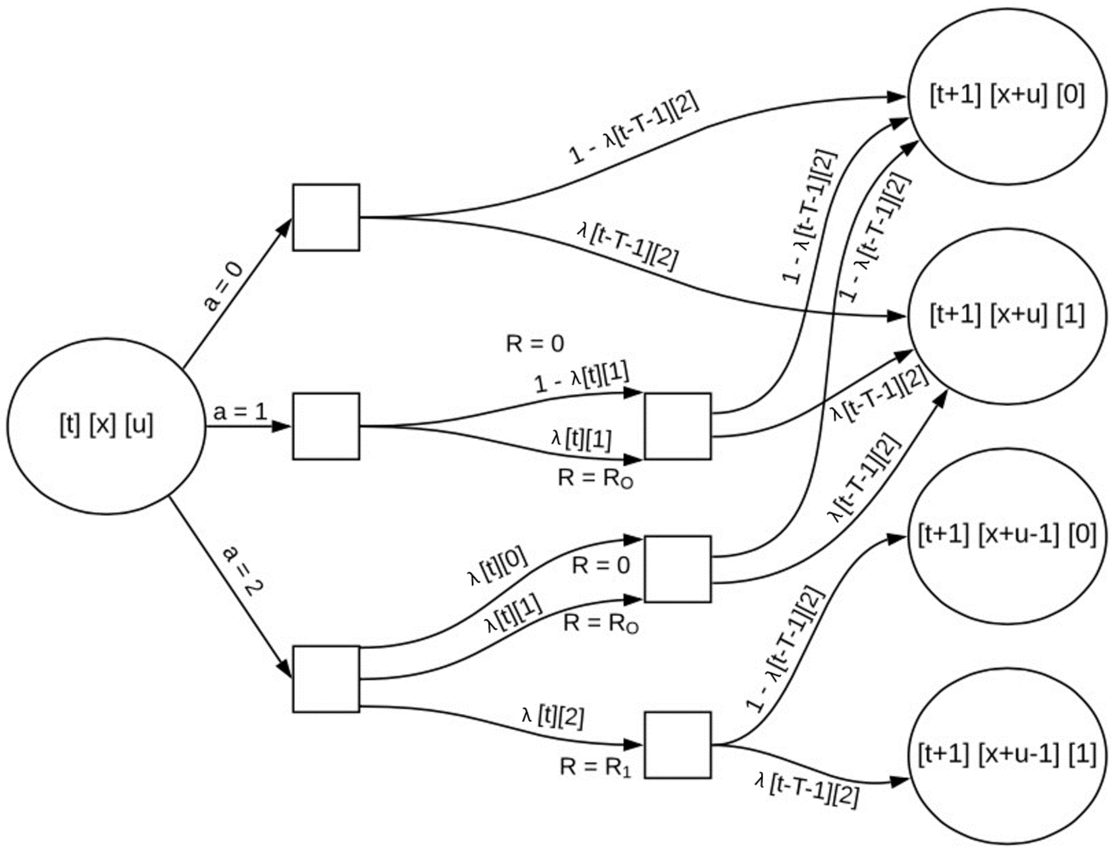


Figure 7.1: Markov Decision Process

Fig7.1 captures the essence of our planning process. Here our model assumes that there is at most one arrival which can be class 1(pay as you go) or class 2(subscription for period T) and hence it follows that $u_t \in \{0, 1\}$ for any period t in our horizon spanning to N. Every State has three available actions with varying rewards. Note that all the following states are accessible if we take action 2, this is due to the assumption that the car rented in pay as you go are available again at the start of the next period. If we relax this assumption this will not be the case. Also note that action 0 is never optimal apart from the boundary states where it is the only available action(when $x_t = 0$). Once we reach the end of horizon any capacity doesn't fetch us any reward and all inventory given for subscription will eventually return beyond the horizon after their respective period expires.

Finding Optimal Policy:

The optimal policy for the horizon spanning to N periods(0-indexed) can be computed using following relationships:

$$V^*(s) = \max_{a \in A} \sum_{s' \in S} \Gamma(s, a, s') \left[R(s, a, s') + \gamma V^*(s') \right] \tag{7.6}$$

$$\pi^*(s) = \operatorname*{argmax}_{a \in A} \sum_{s' \in S} \Gamma(s, a, s') \left[R(s, a, s') + \gamma V^*(s') \right] \tag{7.7}$$

with starting state $s_0 =< 0, C, 0 >$ and end of the horizon boundary conditions
$V^*(s) = 0$ where $s =< t = N, x, u >$ Next we present the above idea in the algorithm we used. Note that the time period of the subscription is fixed in our case and is equal to T periods and every period width is assumed to be same for computational simplicity. After using obtaining $\pi[N+1][C+1][2]$ matrix we can just lookup the optimal action from state and do that. Since the results of action are not deterministic we may reach some other state and again lookup optimal action. We also keep a queue which stores the information of all the cars rented for period T and updates it in each period. we keep doing that until we reach the end horizon

Algorithm 1 Calculate and Store matrix $\pi[N+1][C+1][u]$

Require: N, C, matrix $\lambda[2][N]$,Rewards R_1, R_2
  $dp[N+1][C+1][2]$
  $\pi[N+1][C+1][2] \leftarrow \{0\}$
  $t \leftarrow N$
  $x \leftarrow 0$
  while $x \leq C$ **do**
    $dp[t][x][0] \leftarrow 0$
    $dp[t][x][1] \leftarrow 0$
    $x \leftarrow x + 1$
  end while
  $t \leftarrow N - 1$
  while $t \geq 0$ **do**
    $x \leftarrow 0$
    while $x \leq C$ **do**
      $u \in \{0, 1\}$
      $dp[t][x][u] \leftarrow \max_{a \in A} \sum_{s' \in S} \Gamma(s, a, s') \left[R(s, a, s') + \gamma dp[t+1][x + u - x_a][u_a]\right]$
      $\pi[t][x][u] = \text{argmax}\, dp[t][x][u]$
      $x \leftarrow x + 1$
    end while
    $t \leftarrow t - 1$
  end while
  return matrix $\pi[N+1][C+1][2]$

8

Numerical Experiments

8.1 | Static Models

We design this experiment by assuming Gaussian demand with following characteristics:

- Class 1 : Subscription Plan, with mean demand, $\mu_1 = 200$ and standard deviation, $\sigma_1 = 50$. Each item sold under this class gets us 200 units of revenue
- Class 2 : Pay as you, with mean demand, $\mu_2 = 800$ and standard deviation, $\sigma_2 = 75$. Each item sold under this class gets us 1 unit of revenue.
- Capacity $= 1000$ units. Demand for class 2 arrives before class 1 and all other assumptions of the model have been satisfied in the model

We conducted survey and from there we estimated the aforementioned values. We summarize the results in Fig 8.1. We can observe that average revenue by the model is higher than the first come first serve by 21.4%. Even though this model performs substantially better, its practicality is still questionable. It is seldom observed that the demands of the whole class comes in a sequential fashion and therefore due to this drawback we can not fully apply this in practical Capacity control.

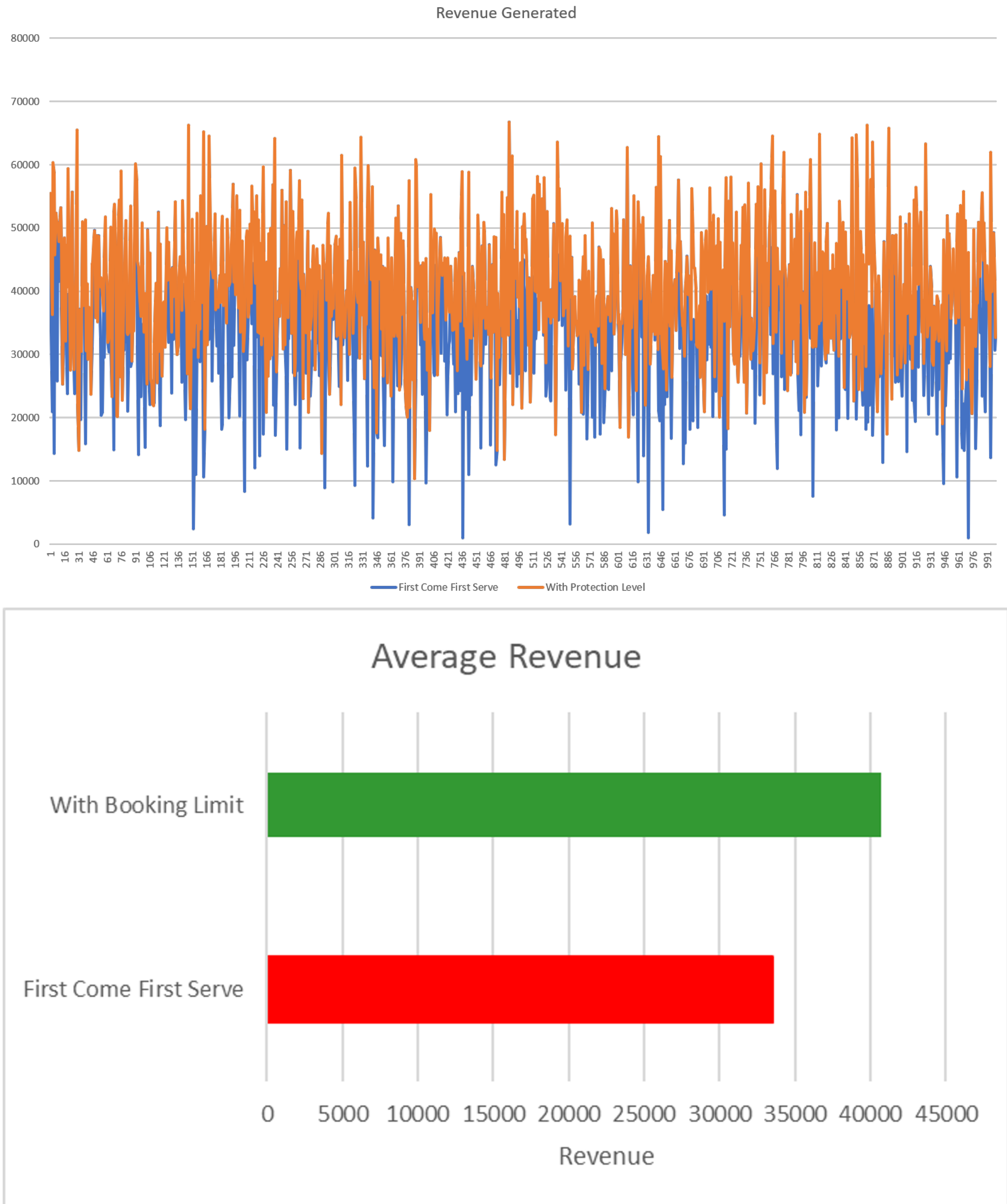


Figure 8.1: Simulation Result of Static Model

8.2 | Dynamic Control : With Replacement

Next we simulate the more practical model.Here for the sake of computational simplicity we have assumed that arrival probability of each class is same for all periods i.e. $\lambda_j(t) = k_j \, \forall t = 0, 1 \ldots, N-1$ and $j = 1, 2$ and each time period is of constant width of 1 hour. In this model our subscription period spans to 30 days i.e $T = 720$ periods. We have two classes. Class 1 : Pay as you go. Class 2 : Subscription plan. Like earlier class 1 reward us 1 unit and class 2 rewards us 200 units. Next the arrival probability of class 1 is taken to be 0.4 and 0.1 for class 2 and 0.5 for no arrival. This is again estimated from our second survey. We simulated the arrival sequence using multinomial trial in each period using random number generator. For each simulation we then tested it on varying capacity from 100 to 1000. We summarize our result in Fig8.2. We observe that on an average the dynamic model generates 8.1% more revenue than first come first serve mode

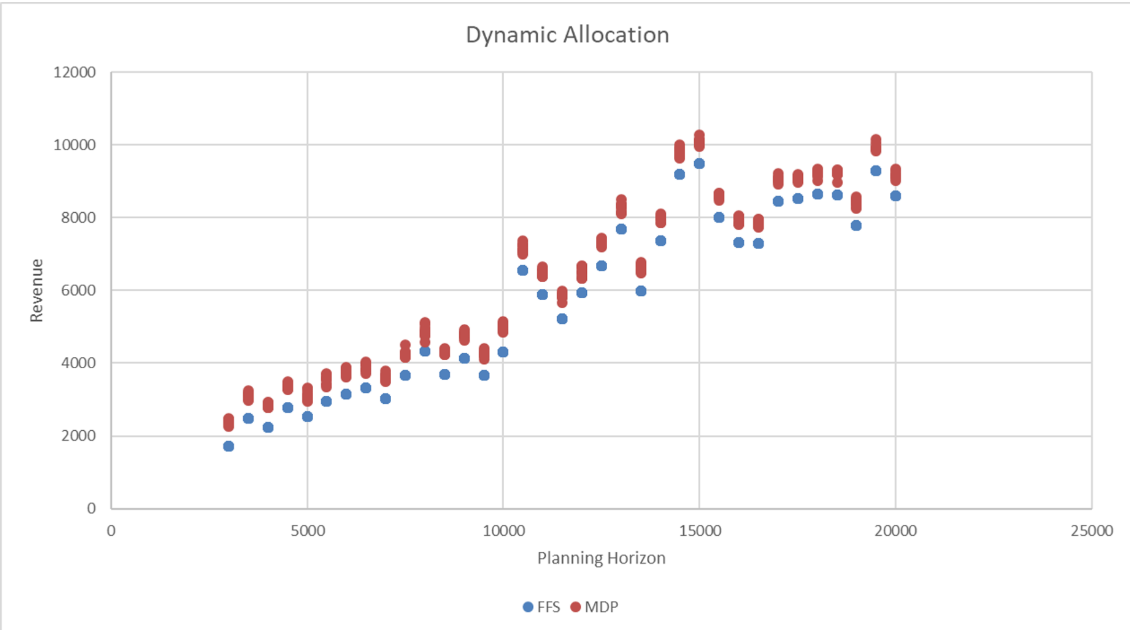


Figure 8.2: Simulation Result of Dynamic Model

9

Conclusions

9.1 | Achieved Aims and Objectives

- Conducted and analyzed customer survey to gain important insights and derive useful approximation from the data so collected which has been used in the subsequent model building
- Analysed Willingness to Pay for potential customers for pricing
- Designed a Markov Decision process with scope of fixed time replenishment
- Constructed a numerical experiment and stimulated it to show that the model proposed performs nearly 8% better than the benchmark model of first come first serve

9.2 | Future Work

9.2.1 | Analysis of Customer Preference

We will incorporate company preference and constraints with the data to accurately predict the utility maximising packages for different customer segments.

9.2.2 | MDP

We wish to incorporate varying time period request in our model along with computationally feasible time varying arrival probability. We also wish to implement reinforcement learning in our model and few more layers to it.

9.2.3 | Numerical Experiment

We also wish to simulate it on more realistic data-set with realistic demand curve. We believe that the true power of our model will be shown in such cases only

9.2.4 | Application

We will get in touch with Zoomcar and collaborate with them on this. Zoomcar can accurately feed us data which will further increase the power of the model and help us in tailoring MaaS suited to the Indian market.

9.3 | Final Remarks

In conclusion, shared mobility models under the umbrella of MaaS hold significant promise in assisting the transition towards more sustainable mobility systems. The analysis of preference, pricing and allocation developed herein contributes a useful extension of agency theory by demonstrating that the wide range of shared mobility business models employed vary in their ability to achieve the goals of the new sustainable mobility paradigm based on the extent to which the business models minimize agency conflicts. We have been able to provide an overview of the connections among the elements of the economic system by which companies can map out pathways to profit. Our analysis suggests that a move toward merit-based business models may offer a more optimal alignment between service provider and local government objectives. Given the rapid growth of the sharing economy, particularly in municipal environments, insights from this research may help shed light on the future evolution of the sharing economy in smart and sustainable city initiatives around the globe.

A

Mobility Solutions

This survey is aimed at designing Mobility Solutions by marketing cars as a service rather than a commodity. For this, we need your opinion on available options.

A.1 | Customer profile and travel pattern

1. Name
   ....

2. Gender
   O Male
   O Female
   O Other
   O Prefer not to say

3. Year of Birth
   O <1960
   O 1960-1965
   O 1966-1970
   O 1971-1975
   O 1976-1980
   O 1981-1985
   O 1986-1990
   O 1991-1995
   O 1996-2000

O >2001

4. Income per annum
   O 0-2,00,000 INR
   O 200k-500k INR
   O 500k-1000k INR
   O 1000k-2000k INR
   O >2000k INR
   O Prefer not to say
   O Not applicable

5. In which sector are you employed?
   O PSU
   O Private
   O Student
   O Self-Employed
   O Home maker
   O Business
   O Other

6. Do you have a Driving License?
   O Yes
   O No

7. Do you own a car?
   O Yes
   O No

8. On an average how many times do you avail Uber/OLA or any other taxi service?
   O Everyday
   O Frequently
   O Rarely
   O Never

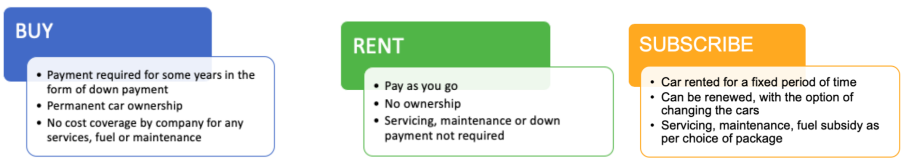
9. On an average how many times do you avail Uber/OLA or any other taxi service?
   O Everyday
   O Frequently
   O Rarely
   O Never

10. On an average, how much do you travel in a day?
    O <50km
    O >50km, but <100km
    O >100km
    O Other

11. On a scale of 1-10, 10 being most important and 1 least, how important is it for you to own a car? (Ownership, as opposed to renting or leasing a car)

A.2 | Preferences

Which one out of the three would you choose for your mobility needs?



(a) I'll buy a car (b) I'll rent a car (c) I'll subscribe for a car

A.3 | Services

On a scale of 1-10, 10 being most important and 1 least, how important would it be for you to have the following services included in a plan for your car?

1. Insurance Cover
   O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 8 O 10

2. Financing Support
   O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 8 O 10

3. Servicing Cover
   O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 8 O 10

4. Maintenance Cover
   O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 8 O 10

5. Fuel subsidy
   O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 8 O 10

A.4 | Payment

The current calculated price of subscribing for a Hyundai i10 car is INR15000 per month, including maintenance and insurance (somewhat less than actual quoted price; this includes full ownership of the car for the given time period). This is just the cost of subscribing, your total cost may be greater if other services and/or accessories have been included.

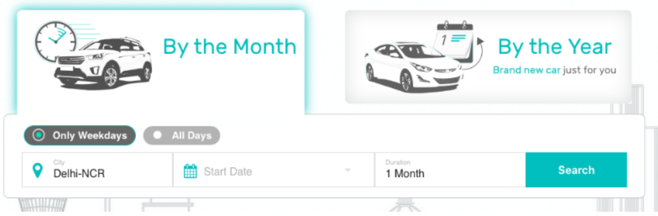


Figure A.1: A snapshot of the subscription service, Revv online

Figure A.2: Revv is a platform which currently enables subscription plans including maintenance and insurance in India. These are fairly common abroad in The States and in EU.

1. Do you currently, on an average, pay more, less or the same amount for meeting your mobility needs?

O More
O Less
O Equal
O Don't know

We would now like to ask you some questions about your response to potential changes in the price of mobility needs. In answering, please bear in mind the following:
1. Assume that your income will stay the same even if the agency prices change.
2. Alternatives do exist for the agency services (i.e. other taxi service, availing you company car service, car pooling etc).

2. Suppose that the price of a car subscription is increased from INR15000 to INR20000. Would you use the agency for your mobility needs if the price were INR20000?
   O Yes
   O No
   O Don't know

3. Suppose that the price of a car subscription increased even further—from INR20000 to INR25000. At this price would you use the agency for your mobility needs if the price were INR25000?
   O Yes
   O No
   O Don't know

4. Suppose that the price increase was less than the previous amount. Suppose the price of a car subscription increased by 15000 to 18000. Would you use the agency for your mobility needs if the price were 18000?
   O Yes
   O No
   O Don't know

5. What would be the highest price you would be willing to pay for mobility needs from the agency? (In INR)
   ....

6. If the agency increased the price of the car subscription beyond what you were willing or able to pay, what would you do?
   O Go without service
   O Go somewhere else
   O Don't know O Other

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