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Investigation of consumer's acceptance of product-service-systems: A case study of cell phone leasing

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ABSTRACT

Product-Service-Systems have been introduced as a practical way to implement the Circular Economy concept. Consumer acceptance of such systems has been a barrier to their widespread implementation. However, it is not clear what contributes to the consumers' likelihood of acceptance of product service systems. This article investigates consumers' acceptance of leasing cell phones instead of buying them through conducting a survey analysis. A regularized logistic regression model has been developed to construct the consumers' decision model. The decision model then has been used to develop an Agent-Based Simulation (ABS) framework in order to model the effects of social influences, previous decisions, and heterogeneous personal traits on consumers' decisions to lease. The results of the study suggest that a segregation exists within the consumer attitudes toward leasing. Meaning that the consumers who are currently leasing their cell phones are more prone to lease again in the future and the consumers who own their current cell phone are more prone to also buy their future cell phones.

1. Introduction

The concept of Circular Economy (CE) has been introduced and popularized to embark upon practical means of resource conservation, while simultaneously satisfying the prosperity necessities of an economic system. The focal point in the CE is to minimize material and value leakage through closing the material loops and recirculating values via reusing, remanufacturing and recycling by ensuring the implementation of the best-known recovery path of used goods. However, while many efforts have been made to apply the CE concept to practical cases, the ambiguity in its definition, intention and purpose may ultimately prevent it from becoming a pragmatic practice (Kirchherr et al., 2017). Various policies have been introduced to pave the way for implementing CE, such as design for longevity (Rizos et al., 2015), promoting reuse, repair and remanufacture (Stahel, 2016), waste-to-energy supply chains and closed resource loops (Bocken et al., 2016). However, factors such as the lack of timely availability of proper information for decision making, lack of implementation of greener technologies, absence of adequate financial support, poor governmental oversight, absence of public participation (Su et al., 2013), increased investment risk (Linder and Williander, 2017), technology readiness, data privacy and lack of customer acceptance (Moreno et al., 2017) have been identified as barriers to the widespread implementation of the CE concept.

Product-Service-Systems (PSS) have been one of the main solutions introduced to overcome the barriers of implementing the circular economy (Tukker, 2004). PSS aim at shifting the consumers from buying the products to leasing them through providing support networks and infrastructures in order to satisfy the consumers' needs while imposing lower environmental impacts (Mont, 2002). However, serious doubts have been raised about consumers' acceptance of such systems. While some advocates of the circular economy promote providing services as a means to relieve the consumers from the burden of ownership via increasing flexibility (Stahel, 2016), others suggest that consumers' response to the lack of ownership is actually the barrier to the successful and widespread implementation of the framework. Particularly in B2C markets, it has been shown that unless PSS provide extra tangible or intangible utilities to the user, their implementation cannot become successful due to the perceptions and behaviors of users (Tukker, 2015).

The aim of the current paper is to shed more light on the decision structure of the consumers' behavior regarding acceptance of PSS. Specifically, we explore the consumers' decisions regarding leasing cell phones versus buying them as an example of PSS. The case of cell phones have been selected due to their prevalence and frequency of use

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and also their environmental burdens when not redistributed through proper recovery channels. Mobile phones are a significant challenge to CE (Hobson et al., 2018). While the global recycling rate of the electronics has been reported to be around 16%, only 3% of the EoL cell phones are being recycled (Hobson et al., 2018) and a significant percentage of them are stored at the owners' homes (Wilson et al., 2017). Because of the significant potential remaining useful life in cell phones, they are great candidates for second-hand markets (Sinha et al., 2016). This acts as a strong drive force for the informal recycling sector. Service systems, such as leasing, can help close this loop by ensuring the collection of the used phones by the formal recycling channels. A survey analysis has been conducted to construct the consumers' decision structure, and later on, an Agent-Based Simulation (ABS) framework has been developed in order to model the impacts of habits, social influences and personal traits on consumers' decisions. This paper contributes to the CE and PSS literature by providing more insights about specific consumers' decisions regarding leasing cell phones. The rest of this manuscript is structured as follows. The second section provides a review of literature about the ambiguities in the CE concept and the corresponding barriers to implement it, as well as the integration of the PSS and smart technologies to overcome such barriers. The third section introduces the method, decision model and the data used in the study. The fourth section provides the data analysis and the ABS framework, the fifth section explains the limitation of the work, and finally, the sixth section concludes the paper.

2. Literature review

While the circular economy has been claimed to provide significant economic benefits, environmental culture, financial barriers, lack of legislative support, information and skills have been introduced as burdens of its implementation in small and medium enterprises (Rizos et al., 2015). Efforts have been made to design and implement technologies, such as waste to energy supply chains, which could enable implementation of the circular economy. For instance, Bocken et al. (Bocken et al., 2016) reviewed various case studies and introduced various product design and business model strategies for slowing and closing the resource loops. However, such efforts still need to overcome various technological, financial, institutional and regulatory barriers (Pan et al., 2014). In another study, Gang et al. (Geng et al., 2012) argued that the lack of standardization of data collection, assessment and benchmarking, coupled with the overlook of the business aspects of CE, hinder its successful implementation. Ranta et al. (Ranta et al., 2017) found that there is a lack of institutional support for the circular economy beyond recycling and there exist culture-cognitive barriers with respect to increasing reuse. The actual challenges that SMEs face while implementing circular economy should be recognized by the policymakers prior to any development of policy frameworks (Rizos et al., 2015). Su et al. (Su et al., 2013) reviewed the implementation of the CE in four Chinese cities. Lack of timely availability of proper information for decision making, lack of implementation of greener technologies, the absence of adequate financial support, poor governmental oversight and absence of public participation have been introduced among the barriers to the successful implementation of CE. In another study, lack of industry motivations and incentives for moving toward green technologies, the absence of financial support and public awareness were introduced as challenges of CE adoption (Geng et al., 2009).

Product-Service-Systems (PSS) have been suggested as a promising and effective way to implement CE (Tukker, 2004). In order to overcome the barriers of implementing circular economy, different domains, departments and perspectives should be integrated (Ritzén and Sandström, 2017). This may be feasible via industry 4.0. Industry 4.0 could provide economic, environmental and social opportunities through the smart and efficient utilization of resources (Kagermann, 2015). Simulation techniques and data-driven decision making can be utilized to assess CE business models based on Re-distributed Manufacturing (RdM) (Vladimirova et al., 2017). Pagoropoulos et al. (Pagoropoulos et al., 2017) conducted a short review on how digital technologies can enable the transition to the CE. Data tracking technologies such as RFID, data integration frameworks such as PLM, and data analysis methods such as machine learning have been discussed. Romero and Rossi (Romero and Rossi, 2017) further explored the CE and PSS by integrating the lean principles into PSS. Petrulaityte et al. (Petrulaityte et al., 2017) introduced distributed manufacturing as a solution to overcome some of the PSS implementation barriers. They argued that several challenges of PSS with respect to customer acceptance, design and development could be ameliorated by the capabilities offered by distributed manufacturing. Moreno and Charnley (Moreno and Charnley, 2016) discussed that digital intelligence and an industry 4.0 framework can enable re-distributed and decentralized manufacturing systems, while also incentivize circular economy by providing more resource efficiency and automation, monitoring and control of flows. However, they argued that it is not clear to what extent the two concepts can be integrated together since there are still various unanswered questions regarding the intellectual property issues, scalability, globalization and management of the business models. Particularly, it is shown that not all the PSS contribute to circular economy and resource efficiency (Michelini et al., 2017).

Wu and Zhu (Wu and Zhu, 2017) introduced a coupled PSS-EPR framework in order to develop a circular value chain for bike sharing.

Cell phones can be good candidates for implementing PSS based on the fast-growing Internet of Things (IoT) technologies (Shih et al., 2016). Sinha et al. (Sinha et al., 2016) recommend support of reverse logistics and product service systems to close the metal flow loop in the global cell phone production systems. Sutanto and Yuliandra (Sutanto and Yuliandra, 2018) proposed a modular design to implement a PSS for cell phones. Rai et al. (Rai et al., 2010) also demonstrated a conceptual design for cell phones under the PSS framework to mitigate generation of e-waste.

On the other hand, the implementation of PSS as a means to develop CE frameworks and the characterization of the PSS have been controversial in the literature (Beuren et al., 2013). While some advocates of circular economy promote providing services as a means to relieve the consumers from the burden of ownership via increasing flexibility (Stahel, 2016), others suggest that consumers' response to the lack of ownership is actually the barrier to the successful and widespread implementation of the framework (Rexfelt and Hiort af Ornäs, 2009). Particularly in B2C markets, unless PSS provides extra tangible or intangible utility to the user, their implementation cannot become successful due to the perceptions and behaviors of users (Tukker, 2015). Lack of trust has been introduced as a certain negative perception toward the acceptance of PSS in the clothing industry (Armstrong et al., 2015). In the case of cell phones, while product leasing and the subsequent guaranteed product recovery by the OEM or the carrier can potentially result in various environmental benefits, it has been shown that awareness of environmental concerns do not translate necessarily into consumer adoption of cell phone leasing, as they cannot connect the two matters (Hobson et al., 2018; Young et al., 2010). Recently, leasing cell phones are becoming more plausible for customers, because it is deemed to be more transparent with respect to the fees while allowing the customers to enjoy the latest gadgets (Darlin, 2017). However, it is still not clear how the consumer decision process is towards the acceptance of cell phone leasing. The aim of this paper is to further explore the consumers' acceptance of PSS. Particularly, we are interested in the case of consumer electronics that have been the focal points of the circular economy discussions aimed at alleviating the electronic waste (e-waste) challenges. This research strives to shed more light on consumers' attitudes and behaviors with respect to leasing cell phones as a means to engage in PSS practices.

Table 1
Examples of different variables in the decision model.

Variable	Design attributes	Consumer Socio-demographics	Attitudes	Usage context	Social influence
Example	• Lease cost • Lease term • Product model	• Age • Sex • Education Level	• Environmental friendliness	• Average usage time • Usage Intensity	• Peer-pressure

3. Method: data-driven simulation modeling of consumers acceptance of leased products

Product leasing is a form of use-oriented PSS in which the ownership of the product remains with the provider (Tukker, 2015), while the customer can utilize the service that the product offers over a certain period of time. Because of the significant potential remaining useful life in cell phones, they are great candidates for second-hand markets (Sinha et al., 2016). This acts as a strong drive force for the informal recycling sector. Service systems, such as leasing can help close this loop by ensuring the collection of the used phone by the formal recycling channels.

While previous studies have shown that the reluctance of consumers regarding the acceptance of PSS is one of the major hurdles of their success (Moreno et al., 2017; Tukker, 2015), it is not yet clear what contributes to the consumers' attitudes toward such systems. A survey analysis has been carried out in order to investigate the determinants of consumers' decisions regarding the usage of PSS. For instance, it is mentioned that the lack of ownership can have a significant effect on consumers' interest level of a PSS (Rexfelt and Hiort af Ornäs, 2009). However, avoiding large upfront expenses for ownership or convenience of lack of accountability for product maintenance can be strong motivations to use PSS (Stahel, 2016).

Another interesting question is the extent to which the consumers are segregated with respect to their likelihood of leasing. Orsdemir et al. (Orsdemir et al., 2018) suggest that service-based systems allow companies to segment consumers based on product use. On the contrary, in product systems, a single product covers all consumers, regardless of usage intensity; therefore, there may be some inefficiencies.

Overall, the following questions are of interest:

1 What are the determinants of consumers' decisions regarding the acceptance and usage of PSS? (e.g., product attributes, service attributes, personal traits, socio-demographics, etc.)
2 How segregated are the consumers with respect to their attitudes toward PSS?

In order to answer the above-mentioned questions, a survey study has been conducted in order to investigate the determinants of consumers' decisions regarding the acceptance of leasing cell phones. Furthermore, the results of the survey have been used to construct an Agent-Based Simulation framework in order to model the effects of previous decisions, heterogeneous consumer attitudes and socio-demographics, social influences and the cost variations on the consumers' likelihood of leasing. First, the decision model will be introduced and then the survey analysis and the simulation analysis will be discussed.

3.1. Decision model and the considered variable categories

Consumer choice modeling, and particularly the use of Discrete Choice Analysis (DCA) models have become popular in the engineering design domain due to their ability to exploit target consumers' preferences and design attributes in order to predict future market demand (Chen et al., 2012). While the usage of DCA in consumer choice modeling has been prevalent, oversimplification of product considerations and users' interactions are among the conspicuous limitations of DCA that require adequate treatment. To overcome such limitations, the use of network modeling and ABS integrated with DCA have been suggested (Mashhadi et al., 2016b; Wang et al., 2015; Wang and Chen, 2015). Moreover, such integrated frameworks could enable the implementation and investigation of the effect of social influence on consumers' choice structure regarding new product adoption (He et al., 2014) and participation in product recovery (Mashhadi et al., 2016b, 2016a; Raihanian Mashhadi and Behdad, 2018).

In DCA, consumers' decisions can be defined based on the desired product attributes, usage attributes of consumers which is definitive of how individuals use the product, the consumer socio-demographics and the social influence and peer pressure for individuals over a time period (He et al., 2014). In this study, we investigate the consumers' acceptance of a PSS (leasing vs. buying) using a similar set of attributes to construct the choice model. In other words, we hypothesize that the consumers' acceptance of leasing a product over choosing the ownership is related to the design attributes of the product and the lease, consumer socio-demographics, consumer attitudes, the usage context, and the social influence. Table 1 provides the types of variables considered in the decision model.

3.2. Survey: investigating the consumers' propensity to lease

A survey study has been conducted in order to explore the consumers' behavior regarding the acceptance of PSS. The respondents were asked about their decisions to lease their cell phones (and consequently return them to the seller) instead of buying them. The survey then was used to construct the decision model, estimating the parameters of the ABS and its validation. An online survey was developed and distributed and most of the participants were students and employees of the University at Buffalo. A total of 112 people participated in the study. Two responses were removed due to incomplete answers, and therefore, a total of 110 responses were used for the analysis. Table 2 summarizes the questions and the corresponding variables they intended to capture and Table 3 summarizes the responses.

4. Data analysis and constructing the binary decision model

All the variables derived from the survey are categorical. The dependent variable is also binary (lease/buy). Therefore, the independent variables have been converted to binary dummy variables and a regularized logistic regression model has been applied to the data. Variables of the elastic net logistic regression can be found via the following objective function using the negative binomial log-likelihood (Friedman et al., 2010):

$$\min_{\beta_0,\beta}: -\left[\frac{1}{N}\sum_{i=1}^{N} y_i.\,(\beta_0 + x_i^T\beta) - log\,(1 + e^{(\beta_0 + x_i^T\beta)})\right] + \lambda\left[\frac{(1-\alpha)\|\beta\|_2^2}{2} + \alpha\,\|\beta\|_1\right] \tag{1}$$

Where β_0 denotes the intercept and β denotes the vector of variable coefficients. The probability of the binary outcome (lease) can be calculated using

$$p(x) = \frac{1}{1 + e^{-(\beta_0 + x_i^T\beta)}} \tag{2}$$

and the binary decision would be selected based on the more

Table 2
Summary of the survey questions.

Survey Question	Variable
Please indicate your gender	S
Please indicate your age category	S
What is your employment status?	S
What is the highest level of formal education that you have achieved?	S
Do you use a cell phone?	
How likely are you to accidentally drop/damage the phone in daily use at home or office or during travel?	U
What is the make and model of your current cellphone?	A
How long have you been using your current phone?	U
Please rank the functionalities below that you use your phone for based on the frequency of use	U
As accurately as possible, please estimate the total amount of time that you spend using your cell phone per day for any type of use.	U
Please rank the mobile apps below based on how frequently you use them:	U
Do you use any life-saving apps to increase battery life on your phone?	U
How do/did you pay for your current phone? (the cost of the device not the cost of the service)	*
If you own your phone how much did you pay for it? (whether by paying upfront or by paying the retail price over installments)	A
If you are leasing your phone (meaning that you can return the phone after the lease term) how long is the lease period?	A
If you are leasing your phone (meaning that you can return the phone after the lease term) how much is your monthly payments (only for the device)?	A
How likely are you to buy/upgrade to a new phone after your lease?	T
As accurately as possible, please select the option that describes you best (with respect to lease/buy decisions among your friends and family)	P
What did you do with your previous phone after you stopped using it?	T
Please indicate how frequently you separate recyclables from trash?	T

Socio-demographics (S), Usage intensity (U), Design/Alternative attributes (A)
Independent Variable (*), Attitudes (T), Peer pressure (P),

probable outcome. In order to find the hyper-parameter of the regularization, λ, hyper-parameter tuning has been conducted. Since the two classes are not balanced (14 respondents selected ‘lease’ and 96 participants selected ‘buy’), cross-validation has been done using Area-Under-Curve (AUC) instead of misclassification rate. Therefore, the regularization parameter has been selected based on maximization of the AUC. AUC represents the diagnostic ability of a binary classifier (i.e., logistic regression here) under different threshold settings using the Receiver Operating Characteristics (ROC) curve that illustrates the true positive rate vs false positive rate of the classifier under different thresholds. Fig. 1 illustrates the results. Moreover, an elastic net parameter of $\alpha = 0.5$ has been selected to balance the effect of the lasso and ridge penalties.

Table 4 presents the regularized logistic regression model fitted to the survey data. The significant variables and their corresponding coefficients in the decision model, as well as the related survey questions from which the variables have been derived, are identified. For instance, “*age.35–50*”, represents that the age category of the respondent was between 35–50 years. Moreover, “*previous.I had to return it because it was a lease*”, “*previous.Sold it*” and “*previous.Traded it for a new cell phone*” refer to the respondents’ decision regarding their previous end-of-use cell phone. As can be seen, the most important variables are education and the previous lease/buy decisions. In other words, the large coefficient of *“previous.I had to return it because it was a lease”* indicates that the current cell phone leasing programs available in the market are somehow binding. Meaning that, if the customers accept such a program, it is much more likely that they stay within a similar contract for their future cell phones. Variables related to the total cost of the lease, peer pressure, usage of battery saving apps and environmental attitudes are also relatively important.

Among the introduced variables, keeping the cell phone longer than 3 years, lack of awareness about battery life-saving apps, the habit of trading old phones and recycling occasionally seem to have a negative impact on the decision to lease. However, relatively lower level education, being previously on a lease or selling the previous phones, strong positive or negative attitudes toward environmental friendliness, peer pressure and the total cost of the lease being between \$400 - \$600 have a positive impact on lease decisions. Nonetheless, while all the variables in Table 5 significantly affect the model (small p values) except education, previous decisions, and strong positive attitudes toward environmental friendliness, the rest of the effects are rather small.

4.1. Agent based simulation

In order to further explore the consumer behavior regarding the acceptance of PSS, particularly to model the effect of social influence and previous decisions, an ABS framework has been developed. ABS is a bottom-up simulation approach in which individual agent decision models can be defined and then the aggregate behavior of the system can be analyzed. Particularly, ABS capabilities are unique in cases in which the interaction between the role players is pivotal for analyzing the system. Utilization of ABS provides us with three unique capabilities:

1 The heterogeneous characteristics of the consumers, such as different socio-demographics and attitudes can be modeled.
2 The effect of social influence and peer pressure can be captured via the interaction of the agents.
3 The decisions of agents can be tracked throughout the simulation and therefore, previous decisions can be modeled for any individual agent whenever they make a decision.

In our simulation, consumers are modeled as decision making agents. A part of the survey data serves as the input to the simulation. The initialization of the simulation has been done using parameter assignment based on the distribution of values derived from the survey data. The socio-demographics and the environmental attitudes remain constant for each agent during the simulation. However, variables related to the cost of the product, previous decisions, peer pressure and usage duration are dynamically calculated while the simulation runs. Eq. (2) using the coefficient values provided in Table 4 has been used as the decision model to calculate the probability of decisions for each agent.

4.2. New product release and market modeling

All the parameters of the simulation are initialized using the values derived from the survey. However, dynamic variables are calculated over the process. When the simulation starts, each agent makes a decision whether to buy or lease a cell phone and starts using the device based on the usage durations calculated using the distributions in Table 5. Every year (365 simulation days) a new product model is released to the market. The consumers who are done using their current cell phones (i.e., their usage duration is over) then have the option to

Table 3
Summary of the survey responses.

Variable	Category	Count
Gender	Female	32
	Male	78
Age	18-25	69
	25-35	37
	35-50	4
Employment	Employed full-time	13
	Employed part-time	12
	Not employed/retired	3
	Student	82
Education	Four-year-college graduate	43
	High school graduate	1
	Postgraduate degree	31
	Some college	34
	Some high school or less	1
Dropping likelihood	Never	6
	Often	10
	Rarely	55
	Sometimes	36
	Very Often	3
Model	iPhone 7	14
	iPhone 6 s	10
	iPhone 7 Plus	9
	Motorola	8
	iPhone 6	6
	(Other)	63
Usage Duration	Less than 1 year	48
	More than 1 year but less than 2 years	40
	More than 2 years but less than 3 years	14
	More than 3 years	8
Daily Usage Time	Less than 1 hour	23
	Between 1-2 hours	30
	Between 2-3 hours	16
	Between 3-4 hours	14
	Between 4-5 hours	4
	More than 5 hours	23
Battery Saving App Usage	I do not know	6
	Not at all	74
	Rarely	6
	Sometimes	24
Previous End-of-Life Decision	I had to return it because it was a lease	4
	I still have it	64
	Recycled it through a third party	7
	Sold it	14
	Traded it for a new cell phone	21
Recycling Frequency	Always	29
	Never	6
	Occasionally	21
	Rarely	14
	Usually	40
Lease/Buy decision	buy lease	96
		14
Estimated Cost	Less than $200	17
	Between $200 - $400	20
	Between $400 - $600	29
	Between $600 - $800	21
	Between $800 - $1000	18
	More than $1000	5
Peer Pressure	All of my friends and family own their cell phones	55
	Most of my friends and family lease their phones but some prefer to own their phones	9
	Most of my friends and family own their phones but some prefer to lease their phones	32
	Some of my friends and family own their phones and some prefer to lease their phones	14

either buy or lease the new cell phone. The cost calculation for the buy option is as follows:

$$\textit{Buying Cost} = \textit{initial price} - \gamma t \tag{3}$$

where t denotes the time passed from the product introduction and γ is the depreciation factor. For the simulation, we assume that $\gamma = 1$. In other words, every new model loses $365 of its value (approximately 40% of its value for most of the common smartphones) over the first year of its introduction, which is in line with cell phone price market trends.

For the leasing option, the cost is calculated based on the remaining value of the product at the end of the lease term:

$$\textit{leasing cost} = \textit{buying cost} * (1 - \alpha^{t_u}) \tag{4}$$

where α is the yearly residual percentage and t_u is the leasing term (usage time) in years. At the point of the decision, if the leasing cost for the agent is $400-$600, the corresponding binary variable in the decision model is changed to one.

4.3. Peer pressure determination

The survey data analysis showed that those participants who selected *"Some of my friends and family own their phones and some prefer to lease their phones"* option are more likely to lease their phones. Based on this observation, peer pressure has been modeled in the simulation as a ratio. Every agent has been randomly and uniformly connected to 1–6 agents to model the consumers' network of friends and family. Then the decision of each agent's friends has been tracked in order to calculate the peer pressure:

$$\textit{peer pressure} = \frac{\textit{number of leases in the network of friends}}{\textit{total number of leases and buys in the network of friends}} \tag{5}$$

Furthermore, if the calculated value for $0.2 < \textit{peer pressure} < 0.7$ then *Peer.Some of my friends and family own their phones and some prefer to lease their phones* $= 1$. Note that, since the decisions of agents can change over time, peer pressure can also change for the same agents at different decision-making instances.

4.4. End-of-use decision simulation

When any agent is done using its current device (i.e., end of usage time), then the agents decide about their end-of-use options (e.g., sell, trade, return and store). If the current device is a lease, then the consumer has to return it. However, if the consumer owns the device, then the end-of-use decision is made based on the probabilities derived from the survey data. These decisions affect consumers' next lease/buy decision via Eq. (2). Note that the lease/buy decision does not occur annually for all the agents. Each agent uses their current device based on a specific usage time, which has been populated from the survey. However, any arbitrary agent, after their usage period is over (this period can be between 0.1 to 5 years), meaning that they would want to obtain a new phone, should decide to either buy or lease the newest cell phone introduced to the market. New cell phone introduction occurs each year, which is in line with the cell phone market trends. For simplicity, options to buy second-hand cellphones or refurbished ones are not considered.

Fig. 2 illustrates the agents' decision process. Table 5 summarizes the global and initial values of the simulation parameters.

4.5. Simulation results

The simulation is run with 500 agents and for 1000 days. Fig. 3 illustrates the trend of the total number of lease/buy decisions (i.e., new product leases or purchases). The simulation has been tested for internal validity using extreme conditions. As expected, the decisions increase over the simulation period in a stable rate that shows the stability of the simulation.

Fig. 4 represents the trend of only lease decisions and the number of consumers who decide to lease (leasees) over the simulation. As can be seen, only about 4% (18 consumers from 500) of the purchase decisions

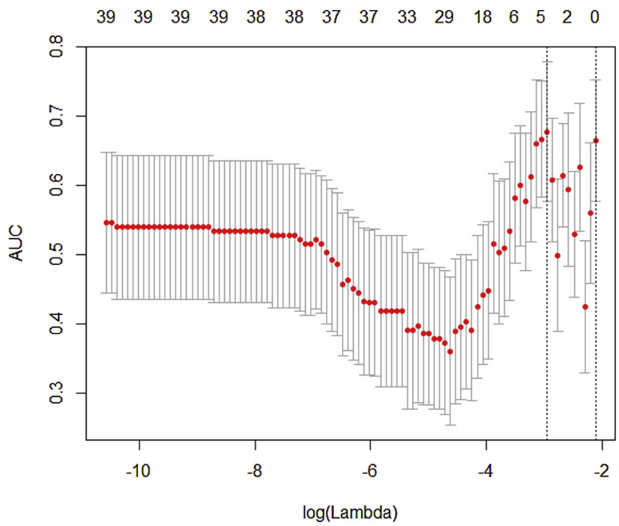

Fig. 1. Hyper-parameter tuning of the regularization parameter. The best λ has been selected based on maximum AUC.

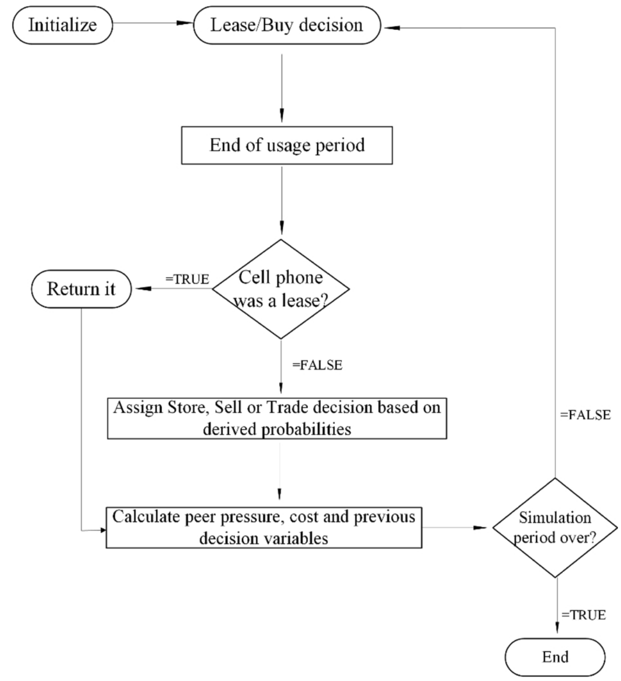

Fig. 2. Decision process of Agents.

Table 4
Summary of the calculated regularized logistic regression model.

Related Survey Question	Variable Name	Coefficient (β_0, β)
	(Intercept)	−2.24
2	\`age.35-50\`	0.88
4	\`education.Some high school or less\`	2.72
8	\`use.age.More than 3 years\`	−0.2
12	\`life.saving.I do not know\`	−0.02
19	\`previous.I had to return it because it was a lease\`	2.06
19	\`previous.Sold it\`	0.07
19	\`previous.Traded it for a new cell phone\`	−0.07
20	recycle.Always	0.5
20	recycle.Occasionally	−0.5
20	recycle.Rarely	0.08
14-16	\`est.cost.Between $400 - $600\`	0.03
18	\`peer.Some of my friends and family own their phones and some prefer to lease their phones\`	0.04

Model Performance: Accuracy : 0.90 Sensitivity : 1.00 Specificity : 0.21 Balanced Accuracy : 0.60.

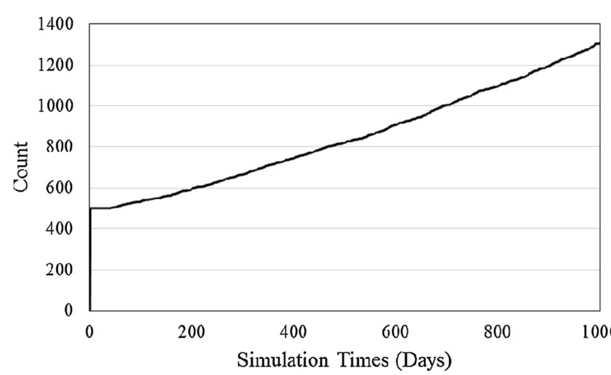

Fig. 3. Total buy/lease decision over the simulation.

Table 5
Parameters of the simulation.

Variable Name	Initiation Value	Type
Number of Agents	500	Constant
Simulation Time	1000 Days	
New Product Cost (initial cost)	800	Dynamic
Number of friends	Discrete_uniform(1,6)	Constant
Age	(35-50) probability = 0.4	Constant
Education	(High school or less) probability = 0.01	Constant
Usage duration	(uniform(3,5) years) probability = 0.07	Dynamic
	(uniform(2,3) years) probability = 0.18	
	(uniform(1,2) years) probability = 0.36	
	(uniform(0.1,1) years) probability = 0.39	
Battery saving apps usage	(I do not know) probability = 0.5	Constant
Previous decision	(Returned because it was a lease) probability = 0.04	Dynamic
	(Sold it) probability = 0.13	
	(Traded) probability = 0.19	
Environmental Friendliness	(Always Recycle) probability = 0.26	Constant
	(Occasionally Recycle) probability = 0.19	
	(Rarely Recycle) probability = 0.13	
Estimated cost	(Between $400-$600) probability = 0.26	Dynamic
Peer.Some of my friends and family own their phones and some prefer to lease their phones	(1) probability = 0.13	Dynamic

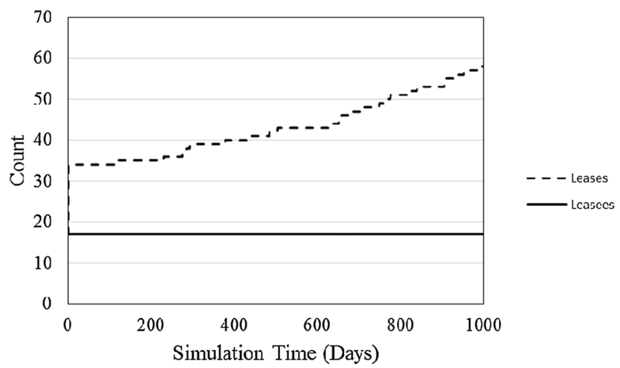

Fig. 4. Number of lease decisions and number of leasees over the simulation period.

are to lease. This result agrees with the model that we derived based on the survey results, and therefore, showcases the internal validity of the simulation. Moreover, another interesting observation can be made as well. Tracking the number of leasees over the simulation illustrates that those who lease their cell phones continue to do so. In other words, the consumers who lease their first cell phone will do the same at the next decision instances. This is due to the fact that the variable reflecting *"previous.I had to return it because it was a lease"* dominates the decision model, such that the effect of peer pressure and other dynamic effects of the model that persuade other consumers to lease become faded. In other words, as we argued above, the lease contracts bind the consumers to stay in the contract. Throughout the simulation, those consumers who started by leasing their cell phones keep leasing; however, no other consumer who previously purchased a cell phone will lease. That is why in Fig. 4 the number of leasees is constant, but the number of leases increases. In other words, the same leasees will keep leasing in their next decision instances.

Another explanation would argue that those who choose to lease perceive higher utilities, such that they are willing to continue to do so. This phenomenon is further confirmed using the survey data. Another part of the survey, which was excluded in the simulation for validation purposes, asked the participants to declare their propensity to lease under certain circumstances. Particularly, the two following questions were asked from the participants:

1 How likely are you to lease your NEXT phone if: [Lease contract duration is increased]
2 How likely are you to lease your NEXT phone if: [Monthly payments are reduced]

The results of these questions are illustrated in Figs. 5 and 6. As can be seen in Figs. 5 and 6, the majority of the respondents who currently

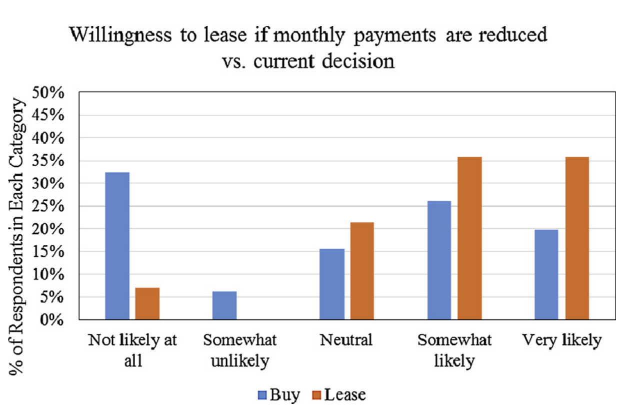

Fig. 5. Propensity to lease the next cell phone if monthly payments are reduced based on the ownership of the current phone.

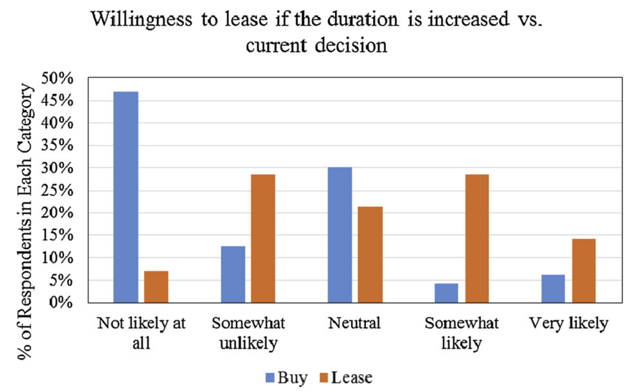

Fig. 6. Propensity to lease the next cell phone if the lease term is increased based on the ownership of the current phone.

own their phones are not likely to lease their next phone, even if the monthly payments are reduced or the lease term is increased with the same cost. However, those who currently lease their cell phones are strongly more interested in leasing their future cell phones under such conditions.

This observation further supports the decision model derived from the survey data and the results of the simulation. It seems that while certain personality traits, attitudes, and social influences affect the consumers' decision to lease a cell phone, they have a minor impact in comparison to the past behaviors or decisions. This may also suggest that the current market is strongly segregated. In other words, a fraction of the market would not consider leasing a *good* option, because of the lack of the ownership and would never consider leasing instead of buying. Similar results have been previously found with respect to consumers' attitudes toward buying refurbished products under discounts (Abbey et al., 2015).

4.6. Sensitivity to price

Previous simulation results, while validating the simulation functionality, did not represent the capabilities of studying the dynamics of the simulation. Based on the survey results, factors such as age, previous lease decisions and education have such a strong effect in the decision function that the changes in the dynamics of the simulation (e.g., cost and peer pressure) had no effect on the agents' decisions. As a result, no agent would switch from lease to buy or vice versa. In order to study the dynamics of agents' decisions, in this section, we focus on a group of consumers who can potentially change their decisions based on different price policies. A simulation is constructed for 1000 days for 500 consumers between 35 to 50 years old, with some high school or less education who have traded their previous phones to get a new one. The rest of the simulation parameters have been set based on the same values in Table 5. Fig. 7 illustrates the trend of percentage of leasees

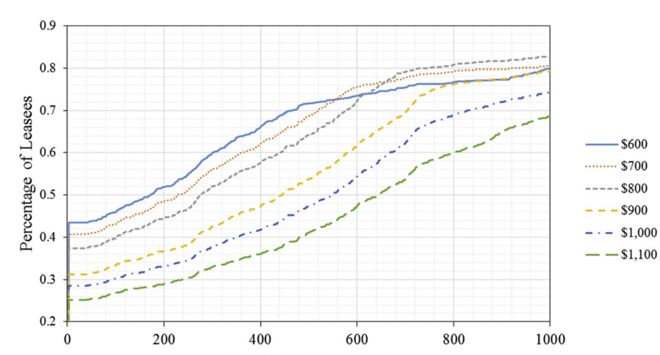

Fig. 7. Percentage of leasees over time for different new product prices.

over time for different values of new product prices. The effect of peer pressure motivates more consumers to accept leasing over time and as a result, the percentage of leasees increases over the simulation. However, the new product price has a negative effect on the consumers' propensity to lease. Note that, the purchase cost and the leasing cost are calculated based on Eqs. (3) and (4). Also, the survey results indicate that consumers are more likely to lease, if the lease cost is between $200 and $400. Therefore, if the introduction price of a cell phone is increased from $800 to $1100 fewer people would consider leasing. On the other hand, based on the mentioned price sensitivity assumption, introduction cost of $700 and $600 increases the chance that the cost of leasing would be less than $200 at the decision point of the consumers. Therefore, based on this fact, the maximum leases happen at $800. This is due to the fact that the survey analysis delineated that the consumers have the most propensity to lease as long as the lease cost is between $200 and $400. Therefore, any change in the introduction cost of a cellphone that results in the deviation of the lease cost from the above-mentioned range (higher or lower) would decrease the chance of leasing. On the other hand, intuitively, the product cost should have a positive relationship with lease likelihood, as the higher the cost is the more the cost gap would be between buying and leasing a product. However, validation of this requires a much larger survey study and is a future work.

5. Limitations

The conducted survey study had a relatively low participation rate. Moreover, most of the respondents belonged to certain socio-demographic groups (i.e., young students), which limits the generalization of the results and the effectiveness of the fitted decision model due to cross-correlation. Also, only a small portion of the respondents were leasing cell phones, which limits the modeling approach and the generalization capability of the results. Therefore, this study can be improved further by expanding the size of the participation set, so that the results can be representative of the whole population.

Moreover, the survey suggested that the most likelihood of leasing happens if the cost of leasing is between $200 and $400. This may be due to the fact that the currently available lease contracts in the market generally cost $400-$600 and the survey result represents the popularity of this price range rather than its definitive effect on the consumers' decision process. Confirmation of this hypothesis should be conducted using a much larger scale survey study in the future.

The assumptions regarding the cost of the cell phones were made based on the recent trends of cell phones introduced by the major companies that hold the majority of the market share (annual release of new models valued > = $800); however, this assumption is not representative of all the market segments. The purpose of the case study was to set an example to showcase the model, and the intention was not to simulate all the dynamics of the market, which is beyond the scope of this manuscript. Also, since usually in financing options the customer pays the whole product value (e.g., here $800), we have not considered financing as a separate option. However, people may not deem financing a phone the same as paying the whole value upfront due to various reasons such as the loss aversion. Nevertheless, such considerations are beyond the scope of this work. Future studies should investigate the effect of various forms of contracts.

Moreover, since in the recent years several providers offer lease options, the carrier plan selection was not considered in the decision process of the consumers. Such considerations entail including various other factors that may influence consumers' decisions such as brand loyalty or retention and are beyond the scope of this work. However, this work can be improved in the future by including the carrier selection decision in the simulation.

6. Conclusions

Product-Service-Systems (PSS) have been introduced in order to implement circular economy by shifting the consumers from buying products to leasing them. Such systems can theoretically lower environmental impacts while creating economic prosperity by directing the used goods into controlled and proper recovery channels. However, consumer acceptance has been identified as one of the most significant hurdles of the widespread implementation of PSS. This article investigated the consumers' decision structure regarding their acceptance of cell phone leasing instead of buying. An agent-based simulation has been also developed to model the effect of social interactions and previous purchase decisions on leasing acceptance attitudes. The results of the study depict that there is an existing gap within the consumers' attitudes toward leasing. In other words, a group of consumers show a significantly strong preference to own their cell phones compared to the other group. Moreover, the results of the survey analysis reveal that, at least for the case of cell phones, previous lease decisions have a strong effect on future leases as well, while factors such as peer pressure and environmental attitudes show a much lower impact.

The framework presented here can be extended to consider various aspects of consumers' decisions. Upon availability of data, other consumers' behaviors related to smart phones (e.g., repair behavior, usage behavior etc.) can be incorporated into the simulation in order to develop a comprehensive consumer decision model.

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