Business System Model of Battery Swapping Management for Transportation Fleet and Energy Storage System

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Abstract:

Electric Express Buses with battery swapping station is a viable business model as they travel long distances and operates on predictable operation routes. Electric vehicles have lower operating cost and battery-swapping strategy could solve the problem of range limitation and long charging time of Lithium batteries. However it requires huge initial investment for extra batteries at depot and long breakeven period. To evaluate system viability of electric express bus business in Malaysia, a system dynamics model is built to model the relationship of stocks, which are the passengers, batteries, buses and swap stations in operation. The model also includes the financial stock in terms of cash flow, book value and net present value to assist the decision making for business growth. The dynamics between operation and finance also modeled in terms of investment delay and financial performance feedback. The simulation also performed What-If analysis to evaluate how the business viability behaves in a dynamic context such as time delay in perceived to invest and size of business expansion. This model can be used to update current scale of the system and to visualize the projected growth. The simulation result can be used to communicate with stakeholders in decision-making process.

Key Word: System Dynamics, Battery Swapping, Electric Express Bus, Battery Management, Decision-Making Model

1. Introduction:

Transportation sector accounts as major contributor to environmental pollution and oil dependency, as majority of the vehicles are internal combustion engine based. Malaysia, as an oil exporting country has started to import oil to fulfill the transportation demand. Electric Vehicle is the agent of change for advent of sustainable transportation as it could be powered by diversified source of energy from coal, hydro, solar, wind, etc. Therefore, Malaysia has proposed an Electric Vehicle (EV) Roadmap to implement policies and regulations to put 2000 buses and 100,000 electric cars on road by year 2020.

Transition of transportation system from oil to electric based takes more than just technology innovation. Innovation in business model is also equally important, as a commercial system is only sustainable by viable business model. Business viability is the fundamental ground of a private company.

Bus is the most important mode of transportation other than personal vehicles in Malaysia. Other than urban transit bus, interstate express buses which run on North South Expressway (NSE) in Peninsular Malaysia is normally operated through public-private partnership. There is an opportunity to accelerate the advent of sustainable transportation by establishing an electric express bus transportation system. Long-range electric bus could be supported by battery swapping management in which is a potential solution for battery capacity/charging constraint. Swapping stations could be built along the NSE to strengthen the infrastructure of energy storage system by renewable energy sources. This system has the potential of providing services differentiation of comfortable ride to long distance passengers, as electric buses are more quite and less vibrating. Electric price is lower a fuel cost, which can lower the operating cost for participating bus operators. Depot batteries can become the energy storage buffer to stabilize grid load and create a demand for renewable energy generation.

The above system has multiple potentials and the technology required is well developed, however it is not commonly seen yet due to the complexity of the system largely in terms business viability. It is very difficult to evaluate the business viability of a new system, which requires being at a certain scale. The conventional way is to estimate the cost of components and subsystems, followed by linear projection without taking account of delay, and feedback of the stock.

This paper aims to model the essential structure of the business system that is a battery swapping management service for transportation fleet and energy storage system. By using system dynamics methodology, the dynamics of business system such as delay and feedback could be modeled. The difference of linear estimation and system dynamics based modeling can be used to understand how the stocks of system could affect each other; points of intervention can be identified for policy design and investment decision-making. This model could serve as a useful evaluation of business viability with better understanding of possible the situation of over-estimation and under-investment.

2. Reference Mode:

2.1 Size of Express Bus Market Demand

The market size of the express bus market in Malaysia is hard to be aggregated therefore the market demand is simplified to the buses that travel on North South Expressway (NSE) in Peninsular Malaysia and only 4 major cities are considered in this market namely Singapore, Melaka, Kuala Lumpur and Penang with respective population of 5.4, 0.85, 1.59, 1.65 million population. Instead of rough estimation of percentage of population, the monthly passenger volume is estimated by number of outgoing buses from each city stations through data collection from an online bus ticket book site, Easybook.com

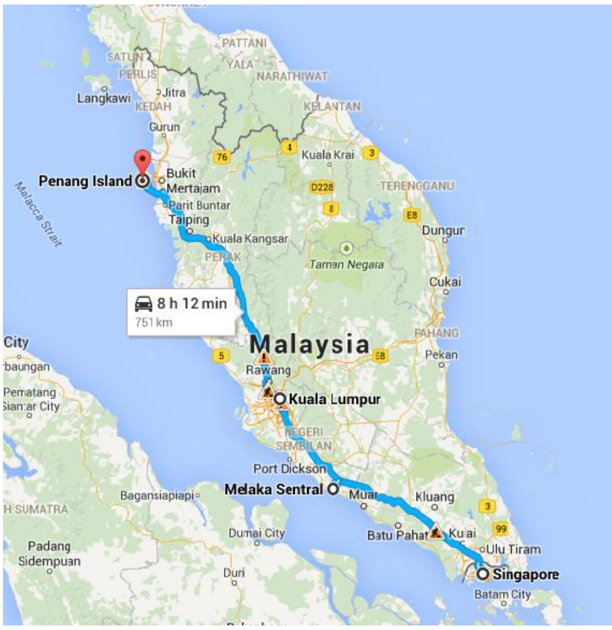

Figure 1: Map view of Express Bus Route in NSE, Malaysia (Source: Google Map)

City Stations	Singapore	Melaka	Kuala Lumpur (KL)	Penang
Singapore	NIL	52	120	16
Melaka	65	NIL	25	15
KL	117	23	NIL	139
Penang	10	16	143	NIL

Source: Easybook.com

Northbound	367	Buses	Daily
Southbound	374	Buses	Daily
Total	741	Buses	Daily
Average passenger	20	People	Per bus
	14820	People	Daily
	444600	People	Monthly

Table 1: 1) Number of daily outbound express buses from 4 major city stations and 2) Estimated number of buses, and average passenger daily and monthly.

Average people per bus	20	People
Swap station daily bus capacity	20	Buses
Bus cost	275,000	USD
Station Capacity Increase Cost	500,000	USD
Battery cost	132000	USD
Station monthly operation cost	500	USD
Bus monthly operation cost	2730	USD
Admin Cost= 30% of bus and station operation cost		
Battery cost	200	USD/kwh
Bus battery	660	KWh (400km)
Daily Mileage	1300	Km
Mileage cost (Electricity)	0.07	USD/km
Mileage price (Diesel)	0.22	USD/km
Driving hours	12	Hours

Table 2: Parameter for Cost Structure.

Monthly Passenger Volume	People	1000	10000	100000	1000000
Number of Bus Required	Unit	2	18	180	1800
Swap Station	Min 2 units	2	4	9	90
Batteries	2 per bus	4	36	360	3600
Monthly Revenue	USD	17160	154440	1544400	15444000
Investment	USD	2478000	12502000	103320000	1033200000
Monthly Operation Cost	USD	6460	51140	495900	4959000
Monthly Admin Cost	USD	1938	15342	148770	1487700
Profit	USD	8762	87958	899730	8997300
Breakeven	Year	23.57	11.84	9.57	9.57

Table 3: Linear Estimation of Business Viability of Electric Express Bus System.

Linear Estimation is a quick reference of business viability for system stakeholders to decide whether the project or business should be performed at the early stage of business. However, the lack of dynamics evaluation could not disclose some of the hidden problems of the system in terms operational and financial level such as delay in physical stock produce, a floating goal for system growth, delay in market response, feedback from cash profit to make new investment, etc.

3. Business System Modeling using System Dynamics Method:

A system dynamics method is used to model the business system of battery swapping management for electric express bus system.

3.1 Model Boundary Chart

Endogenous Variables	**Exogenous Variables**	**Excluded Variables**
Number of User	Cost of Electric Bus	Power Generation Cost
Average user per bus	Cost of Battery	Power Generation Capacity
Number of Bus	Cost of Swap Station	Feed In Tariff
Average bus per station	Cost of Administration	
Number of Battery	Cost per km	
Standard Battery Charging Time	Revenue per km	
Number of Swap Station	Battery Degradation	
Average Battery per station	Electric Bus Degradation	
Profit	Battery Size	
Investment		

Table 4: Model Boundary Chart for the system: Endogenous, Exogenous and Excluded variables.

The model boundary chart above includes the operation parameters for buses, batteries and station as endogenous variables; the input variables are the cost and lifespan of the each stock, and the revenue and price of the service and stock. Power Generation Capacity and Generation are excluded in this system as the source could be varied from time to time and is not a stakeholder interest at the moment.

3.2 Time Horizon: 10 years is a typical period of 2X the lifetime of commercial electric vehicles and batteries. 100-month time scale is used to model at least over one cycle of the stock lifetime.

3.3 Scenario: Dynamics analysis for business viability will uncover unwanted side effect of business growth due to over-estimation in the beginning of business planning and under-investment during operation process.

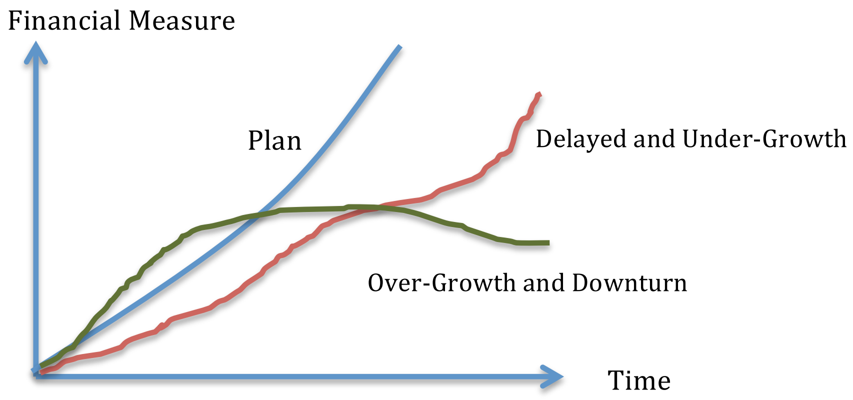

Figure 2: System Growth measured in financial term over time

3.4 Subsystem Diagram

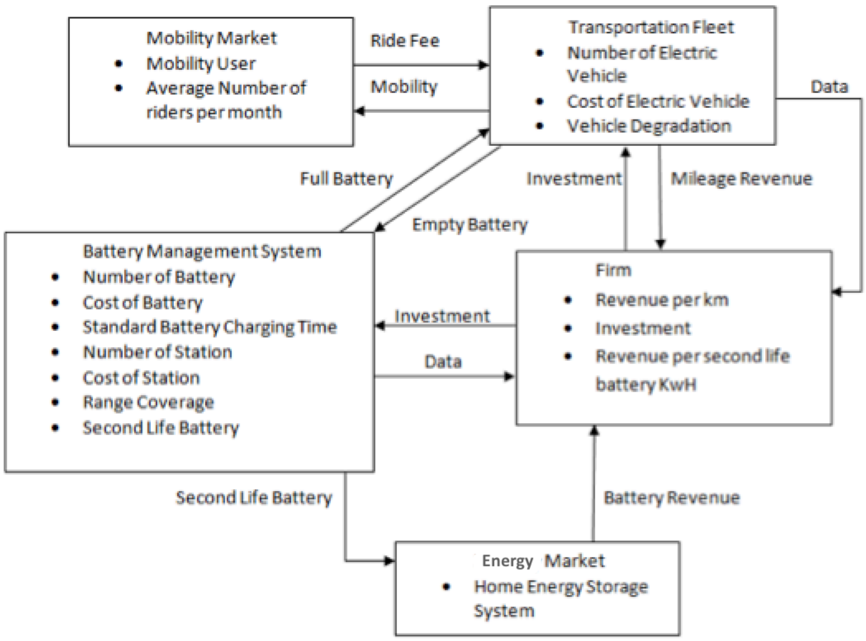

Figure 3: Subsystem diagram of the system describing the interaction of the various subsystems in this business model.

The subsystem diagram includes major stakeholders related to this system. The Firm is the system of interest, which manages the battery swapping system to provide swapping services to the Transportation Fleet and used stock to Energy Storage Market. Mobility Market is satisfied by Transportation Fleet e.g. Electric Express Bus in this case.

3.5 Causal Loop Relationship and System Archetype

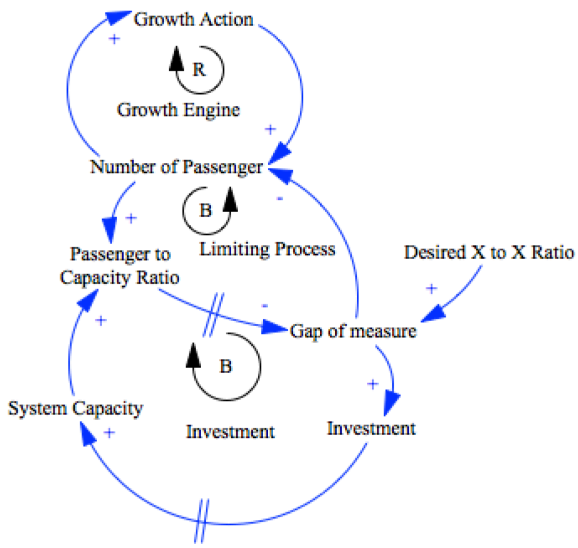

Figure 4: Causal Loop Diagram of Demand Growth, Inhibiting Process and Investment Delay forming a system archetype of "Growth and Underinvestment".

The essential structure of this model is the growth of system capacity to accommodate demand from passenger. As passenger base increases, the system performance will increase up to its capacity limit. However, if the system underperforming or failed to accommodate passenger demand, there is a gap between the standard which is "Desired X to X ratio" and the performance which is "Passenger to Capacity Ratio", it will trigger the need for investment to scale the system for market growth or else, the excessive passenger will leave and the stagnate the system growth. The delay of investment to increase system capacity will likely delayed the system growth and become under-investment compared to the planned growth. The delay of feedback in gap measure would cause the scheduled investment system to be overgrowth and the excessive cost causes the system growth going downturn. System Archetype of Growth and Underinvestment is identified from this diagram.

3.6 Stock and Flow Diagram

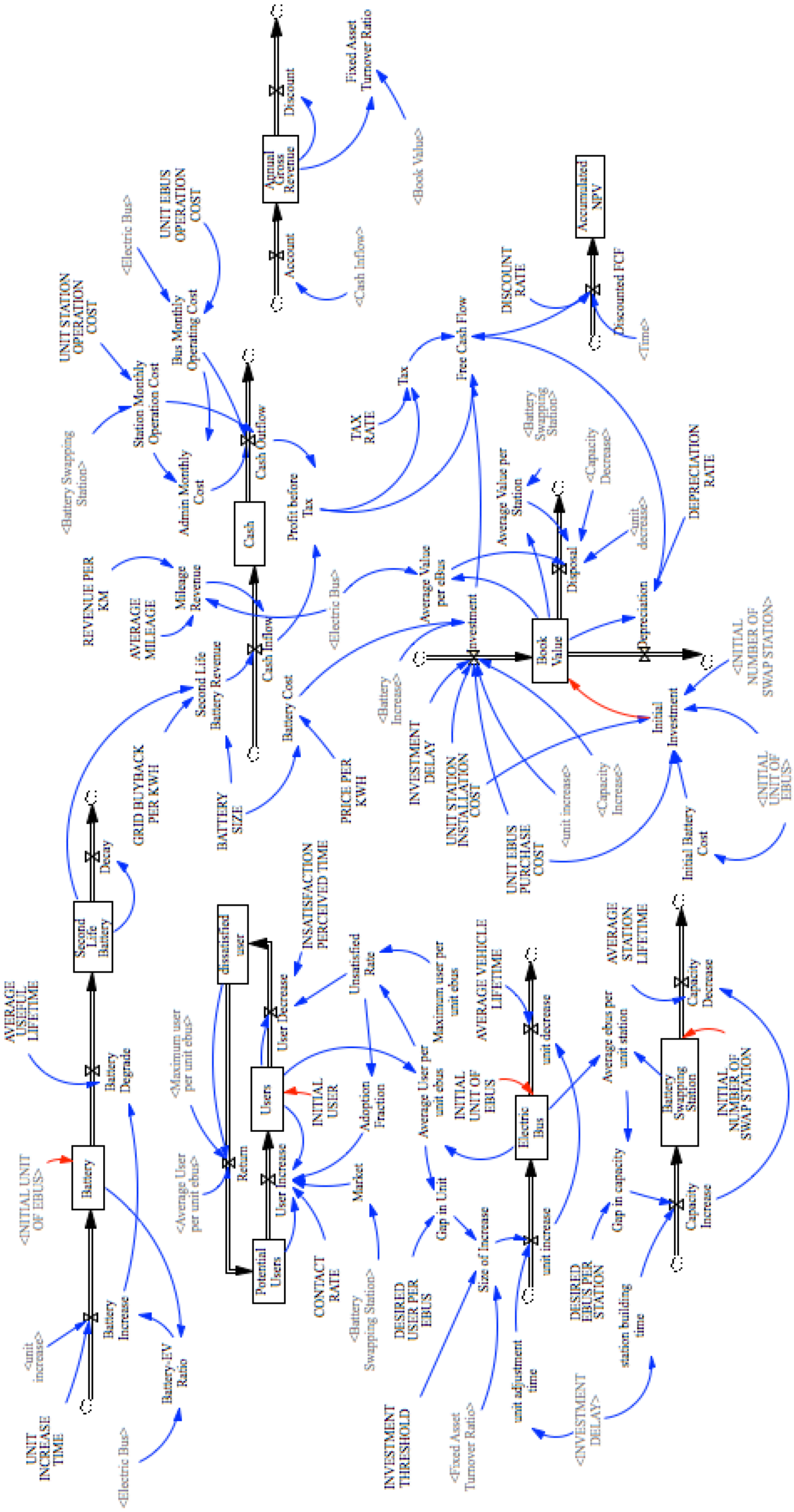

Figure 5: Model Overview

3.7 Model Overview

Based on the causal loop diagram, the variables are formulated to form inflows to the stocks. In this system there are two models: operation and finance. Operational Model includes the variables of the physical system namely "Electric Vehicle", "Battery" and "Swap Stations". Financial Model links the information of physical and its inflow to "Cash", "Book Value" and "Net Present Value (NPV)". In this stock and flow diagram, the physical systems with different life spans can be modeled as to know how it affects the cash flow, the change of book value and the projected NPV.

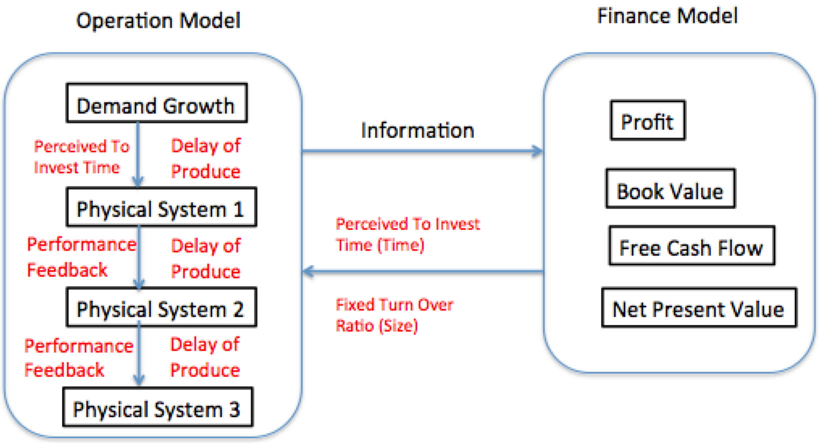

Figure 6: Model Overview shows the dynamics between and within the systems

The dynamics of investment delay and financial performance feedback from Financial Model to Operational Model could be modeled by variable such as "Perceived to Investment Time" and "Fixed Turn Over Rate". Input settings can be altered to check the current position in the model. The model can be used to communicate with other stakeholders to design a more appropriate operations, business strategy and investment outlook.

3.7.1 Formulation of Model: Operational Model

3.7.1.1 Passenger/User Growth Model: SIR Model

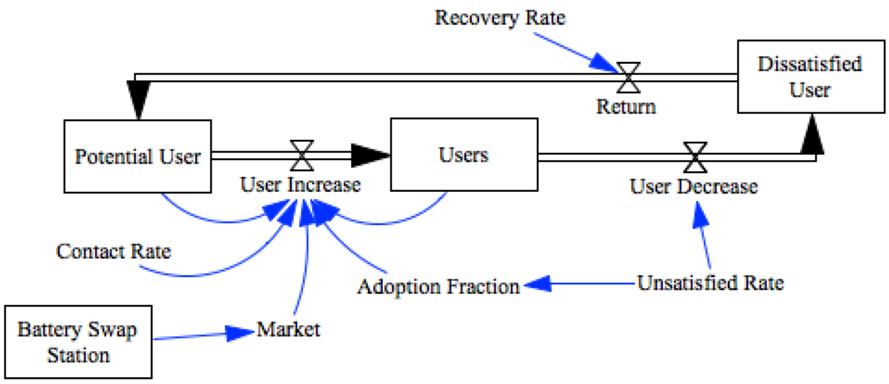

Figure 7: SIR Model for Passenger Growth

To simulate the diffusion growth of user base, SIR (Susceptible, Infected, Recovered) diffusion model is used to model the movement to potential users to users and non-users. User increases through two ways: Contact Rate (advertisement) and Adoption Fraction (word of mouth effect). The market is also growing through the increase of Battery Swap station as it covers more range and serves more regions. User decreases if there are not enough buses to the serve customers and causes dissatisfaction. However, if the average user per bus is below the maximum capacity, the dissatisfied users would go back to potential user pool.

3.7.1.2 Electric Bus-Battery-Swap Station Model: Co-flow of Stock with Floating Goal

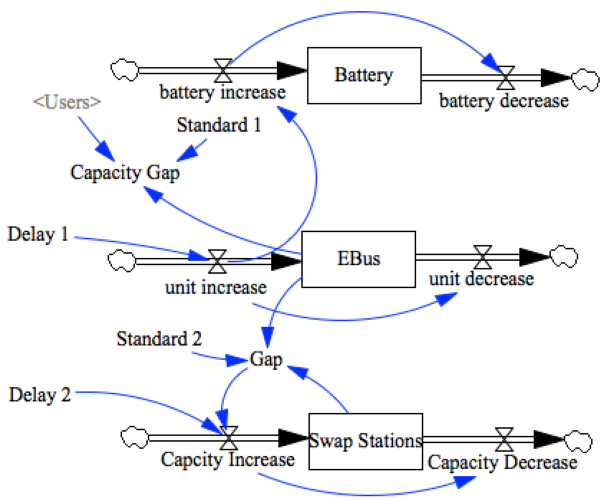

Figure 8: Co-flow of Ebus, Batteries and Swap Station as system capacity increases

The number of Electric Bus (Ebus) increase based on a metric known as Average User per Bus. Bus operators can decide how many buses to increase based on the Gap in Unit, which is the difference between Average User per Bus and Desired User per Bus. In this case, Electric Bus and Battery are separate stock due to the number of unit is difference and both stocks have different lifespan. Electric Bus degraded in 6-7 years in general but battery generally retaining only 80% of capacity after 3-5 years had been used as a automotive battery. However, these batteries can be used as second life battery for energy storage battery of home or facility building use. By default, one bus will need to have 2 batteries, one is onboard moving with the bus, another one standby being charged at depot in battery swap station. Note that the bus degradation is a pipeline delay and the battery degradation is first order delay.

Based on the number of batteries and buses, the capacity of swap station will be increased based on the metrics Average Battery per Bus and Average Battery per station. Capacity decrease of the Swap Station is a pipeline delay. If the amount of batteries is more than twice the number of Bus, it could mean that the charging capacity of the station is insufficient to charge the batteries full for the incoming bus for swapping, the charging capacity of station should be increased. If the Average Battery per station is too high, it could mean too few stations to cater the buses for swapping, more station should be established to reduce congestion.

3.7.2 Formulation of Model: Financial Model

3.7.2.1 Cash Flow Model:

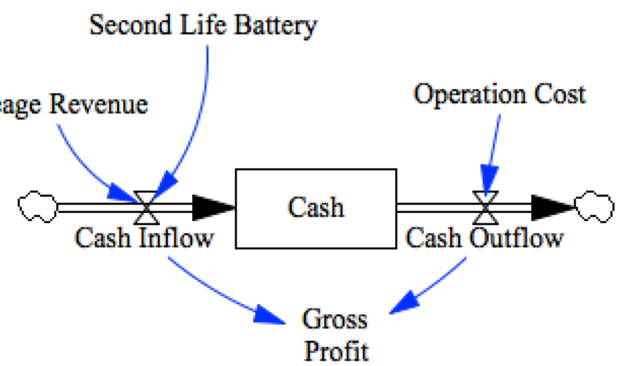

Figure 9: Cash Flow Model

The cash flow model will examine the profitability of the operation. Cash Inflow comes from mileage fee of buses. Electric Buses will cost lesser than Engine Bus, as long as the cost per km fee is lower than diesel fuel (0.3 USD per kilometer), this is a major savings for transportation fleet. The second source of income could come from sales of Second Life Battery. Cash outflow is the expenses of the cost of maintaining the swap stations and buses. The administration cost the system which is assume to be 30% of maintenance cost of buses and stations is also being included in the cash outflow. The difference of the cash inflow and outflow will be the profit and stocked as cash.

3.7.2.2 Book Value, Cash-flow and NPV accumulation Model:

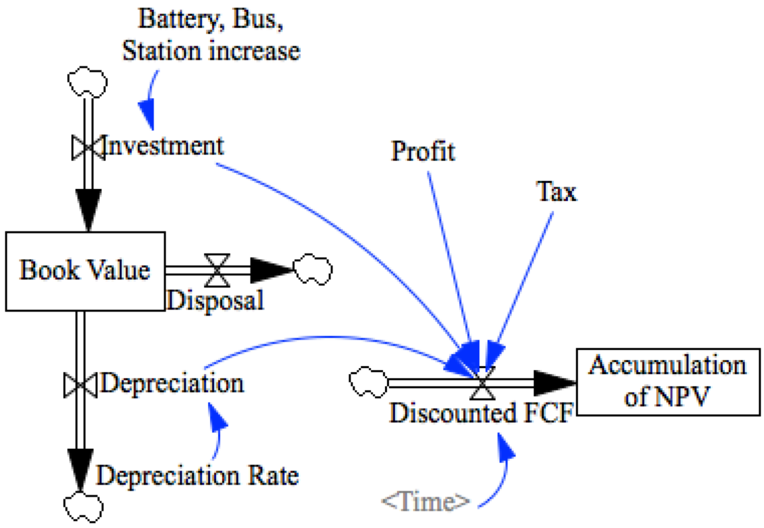

Figure 10: Financial Model of the Business System

When the firm decide to invest in more buses and swap stations to expand the business. The book value stock flow will capture the investment inflow, which consists of cost of unit battery increase, unit station capacity increase, and unit bus increases. Book Value measures the worth of the system. For simplicity, it divides 50-50 of the value for both station and bus as they are treated as asset to the company. Meanwhile batteries are the commodities that will be sell as product when it is degraded as static energy storage unit. There are two outflows for Book Value stock. First being the disposal flow as bus and station reaches their end of life. Second outflow is the depreciation outflow to show that the value of the asset is decreasing its value at a certain rate in books.

The final stock flow is Net Present Value (NPV). This flow is being used as a metric to measure the whether this system is worth investing by bringing forward the future value to present. The inflow of NPV comes from Free Cash Flow variable. Free Cash Flow is the sum of After Tax Profit and Depreciation of asset minus Investment. It is an important indicator to see if the firm still be able to generate real cash to enhance shareholder value after operation and capital expenditure.

Free Cash Flow (FCF) = (Revenue-Expense)*(1-Tax Rate)+ Depreciation-Investment

Putting all this stock flow in one model is very convenient for entrepreneurs and stakeholders of a new business to check whether this business system is scalable in the long run and still being able to generate cash flow and possess positive NPV. At the same time, while running the business, entrepreneur could check which parameter to change or which area to scale and improve to increase profitability or convince investor to put more money in to expand for greater good.

3.7.3 Dynamics between Operation and Finance System Models

Previous formulations focus on building models for operation and finance system. The information of physical stock in operation is fed to finance system to do accounting process. The costing model is one-way and rather static. Therefore this paper accounts time delay and performance feedback as the dynamics element between Operation and Finance System Models. “Investment delay” in the operation model caused by the variable “Perceived to Investment Time” in the financial model. “Fixed Asset Turnover Ratio” is formulated as Annual Gross Revenue over Accumulated Book Value. It shows the revenue generated of $1 investment in asset. Having this ratio for investment evaluation decision, an investment threshold can be used to adjust the size of operation expansion. The feedback of financial performance to operation is therefore formed.

$$\text{Fixed Asset Turnover Ratio} = \frac{\textit{Annual Gross Revenue}}{\textit{Accumulated Book Value}}$$

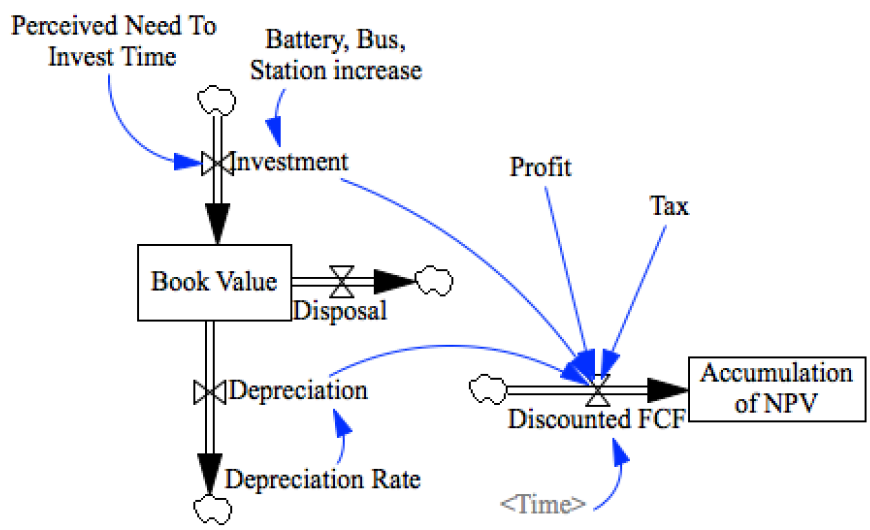

Figure 11: Perceived Need to Invest Time in Financial Model

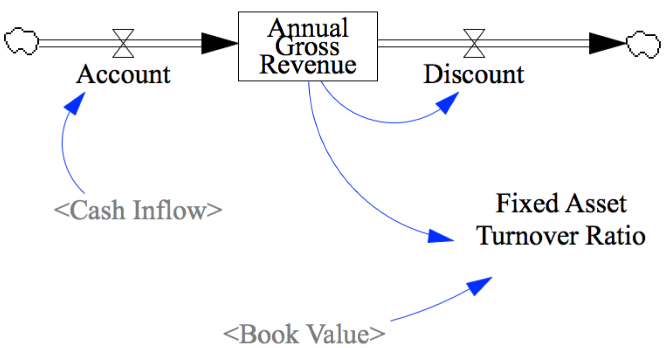

Figure 12: Fixed Asset Turnover Ratio Model

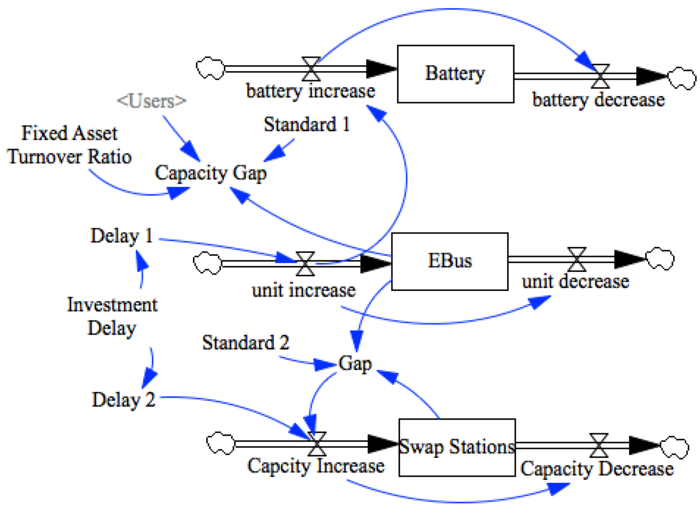

Figure 13: Time Delay and Financial Performance Feedback in Operation

3.8 Evaluations and Discussions

The main goal of this model is used for reviewing the financials of operations. The left side of the model mainly deals with user base, unit of assets and product, which are batteries, vehicles and swap stations. The right side of the model captures the financials like monthly cash flows, book value and net present value. This model is a general decision making model for operation expansion and financial project in the longer run. Evaluation of a business system can be done in statically and dynamically. First of all, Projected Growth of a business can be visualized by inputting system parameter. Secondly, the business system can be tested dynamically by adjusting perceived to invest time in finance model to cause investment delay to operations. Size of system capacity expansion could be altered by adjusting the investment threshold based on fixed asset turnover ratio in finance model.

Input Parameter for System Testing:

Average people per bus	20	people
Swap station daily bus capacity	20	buses
Bus cost	275,000	USD
Station cost	700,000	USD
Battery cost	132000	USD
Station monthly operation cost	500	USD
Bus monthly operation cost	2730	USD
Admin Cost= 30% of bus and station operation cost		
Battery cost	200	USD/kwh
Bus battery	660	kwh
Daily Mileage	1300	km
Mileage cost	0.07	USD/km
Mileage price	0.22	USD/km
Driving hours	12	Hours

Contact Rate	0.5	ratio
Adoption Rate	0.3	ratio
Investment Delay	6	months
Investment Threshold	0	ratio
Depreciation Rate	15%	annum
Discount Rate	20%	annum
Tax Rate	26%	annum

3.8.1 Graphical Result 1: Projected Growth Visualization

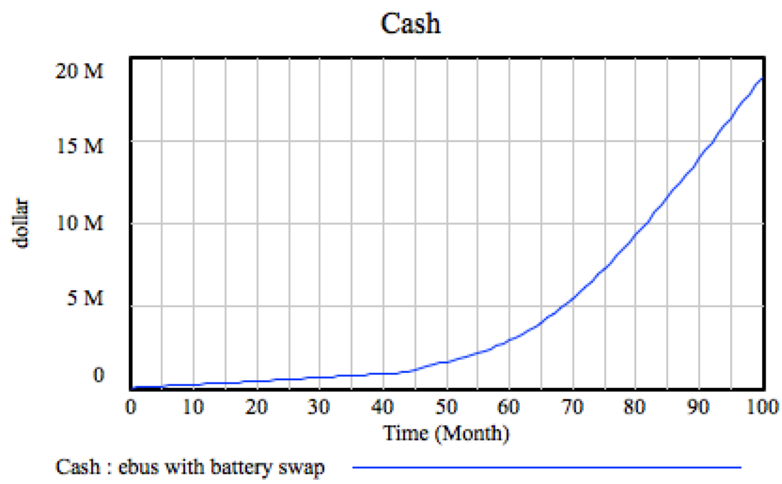

Figure 14: Accumulated Cash

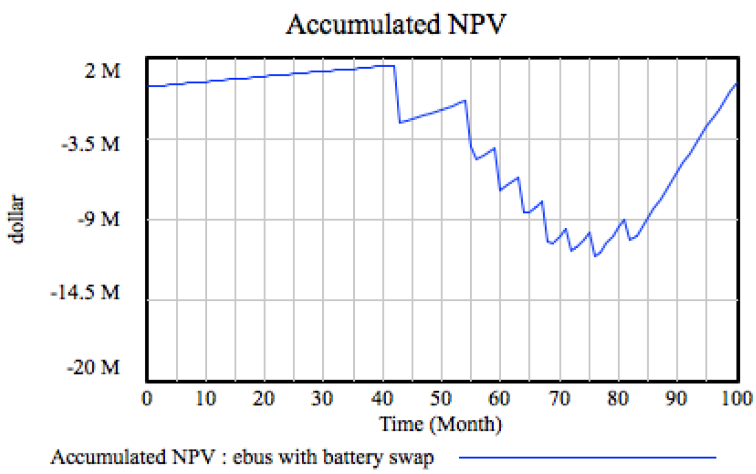

Figure 15: Accumulated NPV of annual discounted rate of 0.20%

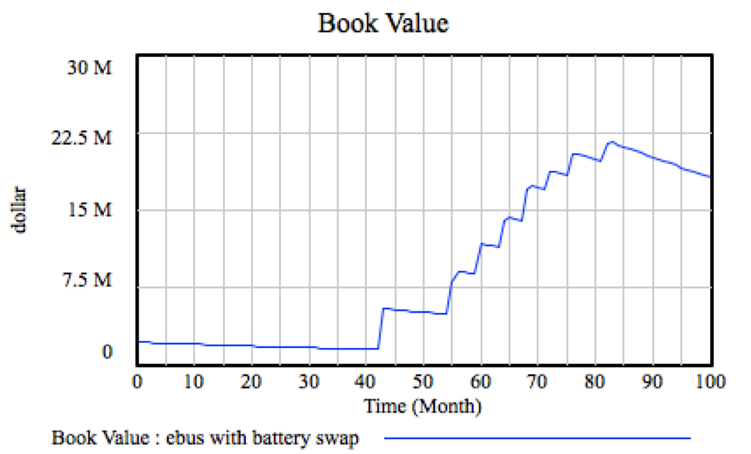

Figure 16: Book Value of system asset (Battery, Swap Station and Bus)

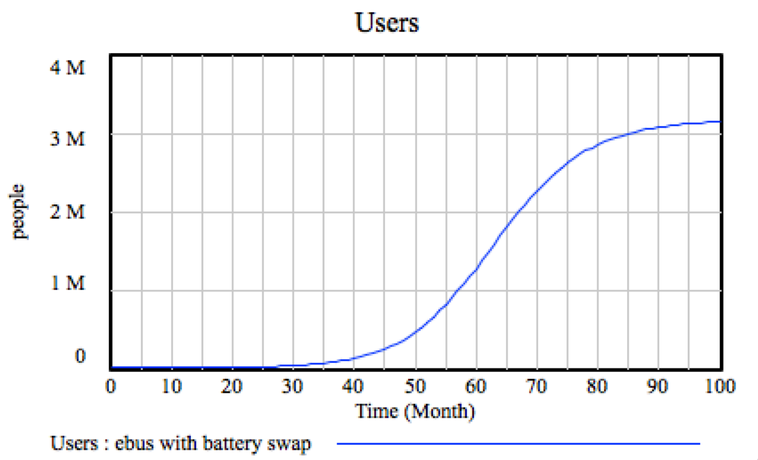

Figure 17: User growth till market saturation

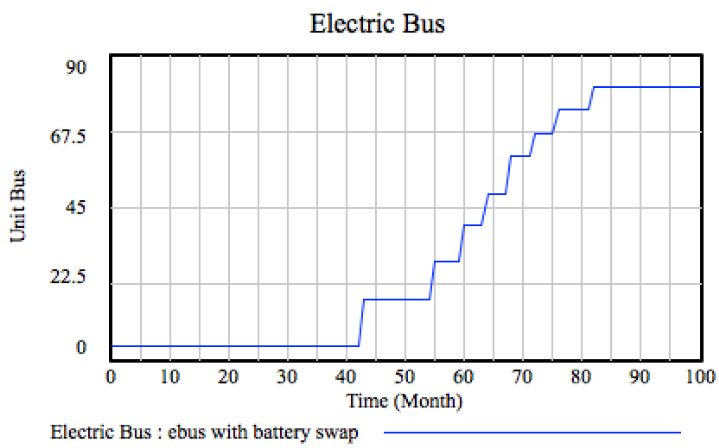

Figure 18: Electric Bus stock for total market

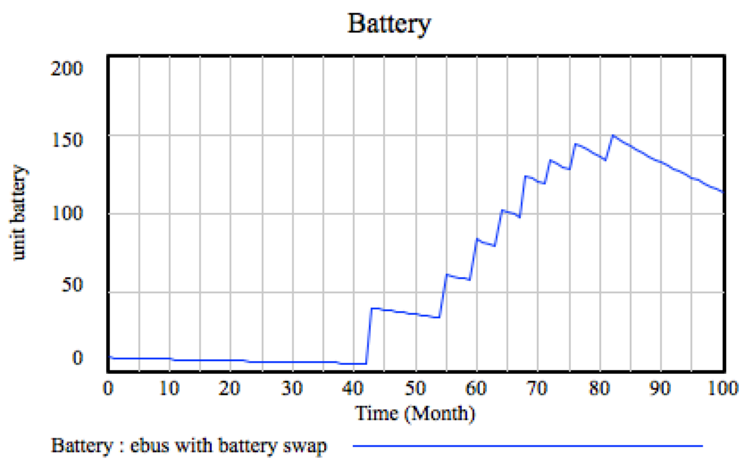

Figure 19: Battery Stock for the system

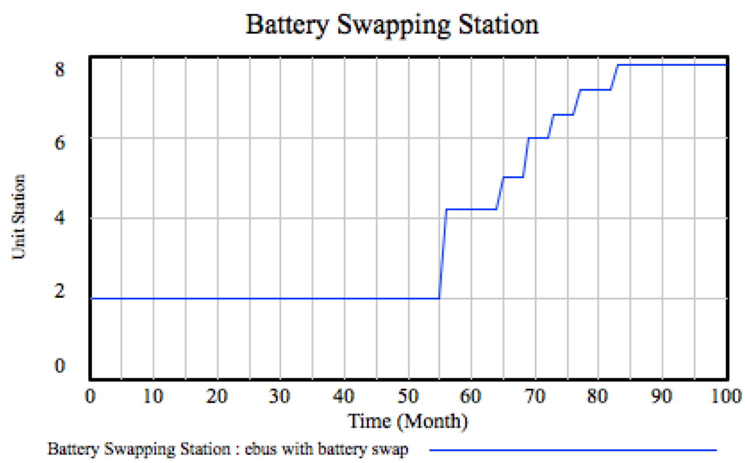

Figure 20: Battery Swap Stations stock after system stabilizes.

When the price of mileage (0.22 USD per km) is about 3 times the cost of mileage (0.07 USD per km), and setting the cost of battery (200 USD per kWh), bus (275,000 USD) and the station (500,000 USD). Cost of system administration is assumed to be at 30% of the sum of bus and station operation cost. The firm could generate enough cash flow from its revenue to gain positive net present value accumulated at the discounted rate of 20% annually over 10 years. It shows that at this cost point, battery swap station for electric express bus is a feasible business.

3.8.2: What-If Analysis 1: System Delay

Perceived Time to Invest is set as manipulating variable at 1, 3, 6, 12 months while investment threshold is fixed at 0 meaning aggressive business expansion will be performed as long as the system is generating revenue. Result of the analysis is illustrated in terms of cash inflow and net present value of the system.

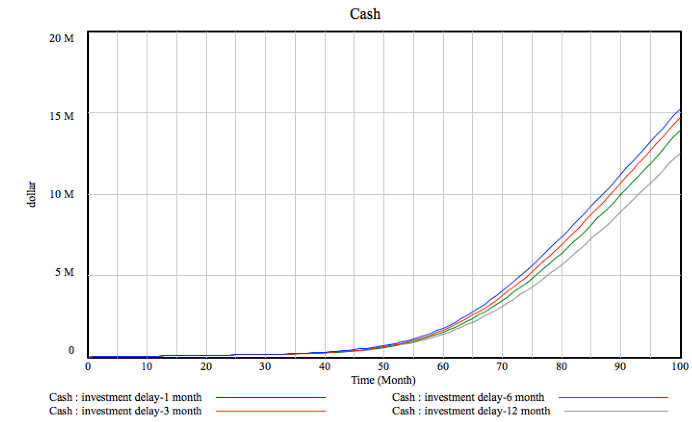

Figure 21: Cash Inflow of the business at various investment delay period

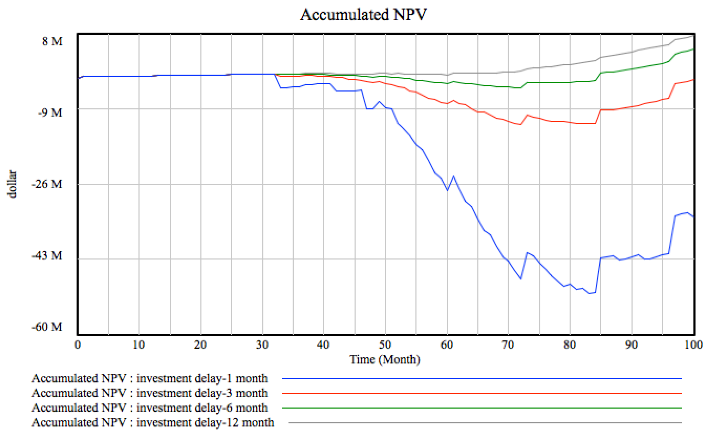

Figure 22: Net Present Value of the system at various investment delay period

Business will experience negative NPV due to the delay in the system. Aggressive expansion will cause the system overgrowth to a point that jeopardizing the viability of the business. Sometimes it is better to stay undergrowth until the system is stabilized.

3.8.3 What-If Analysis 2: System Feedback

Investment Threshold is set as manipulating variable at 0, 0.5, 1, 2 while Perceived to Invest time is fixed at 12. Result of the analysis is illustrated in terms of user growth and net present value of the system.

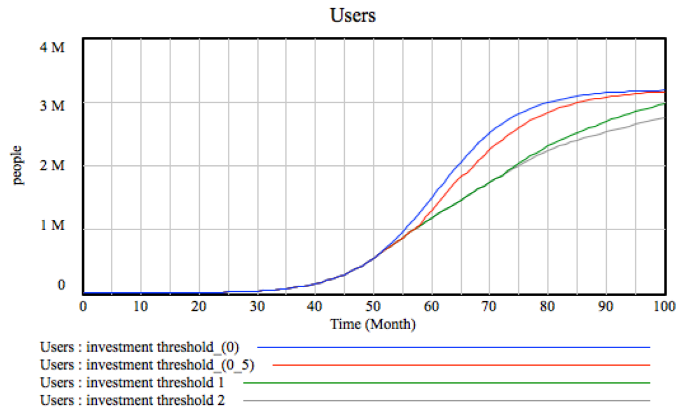

Figure 23: User growth at various system capacity expansion sizes

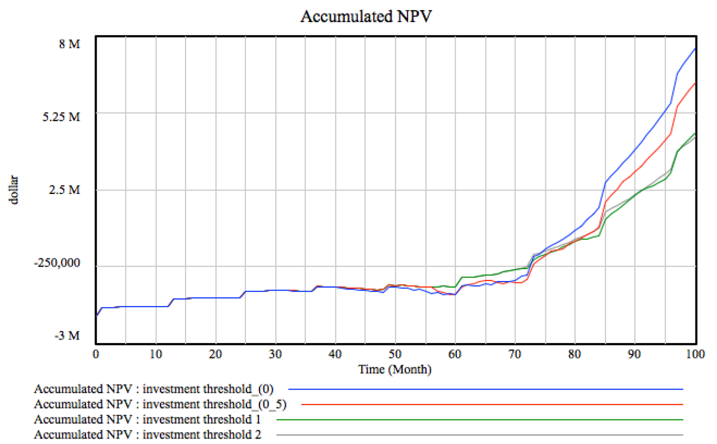

Figure 24: Net Present Value of System at various system capacity expansion sizes

User growth and NPV of system behave proportionately to capacity expansion as expected. In some cases where credit is available, aggressive expansion is possible to accelerate user growth. In other cases where financial health is strictly monitored to preserve shareholder value, higher threshold is set at value higher than 1 to ensure revenue is generated more than the asset investment before decided to expand the system.

4. Limitations and Future Work:

This model has included important dynamics factors like delay of investment return, physical produce and investment in system capacity. This model assumes the investment is available when it is needed, however this is not happening in real. A feedback from cash pool is needed to show the profitability for fundraising activities, such as new investment, bank loan and government grant. Optimization of the model can be done as future work to find out the best mix of number of battery per bus or number of stations for overall system cost minimization.

5. Conclusion:

Business System Model is developed in this research. The result complies with the reference mode in terms of user, revenue growth and breakeven year. However, dynamics based business system model could evaluate the business viability in times when the system growth to a scale where it has to accommodate negative NPV at month 50 due to delay in cash flow. This model can be used as a basic model before developing Management Flight Simulator for stakeholder to adjust the parameter based on their best interest. As a whole, dynamics based evaluation could give more confidence for business stakeholders to evaluate business viability.

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7. Appendix

Table of Formula:

80% retain lifecycle=48; Units: months
Accumulated NPV= INTEG (Discounted FCF,-Initial Investment) ; Units: Dollar
Admin Cost=0.3*(Bus Monthly Operating Cost+Station Monthly Operation Cost); Units: Dollar
Adoption Fraction=0.3-Unsatisfied Rate*0.5
Average ebus per unit station=EBus/Battery Swapping Station
Average Lifetime of station=100; Units: months
Average Lifetime of unit vehicle=84; Units: months
Average Mileage=1300*30; Units: km*day
Average User per unit ebus=Users/EBus/30
Average Value per eBus=0.5*Book Value/Ebus
Average Value per Station=0.5*Book Value/Battery Swapping Station
Battery= INTEG (Battery Increase-Battery Degrade,Initial unit of ebus*2)
Battery Bus Ratio=Battery/Ebus
Battery Cost=Battery size*Price of Battery; Units: dollar per KwH times battery size
Battery Degrade=Battery/"80% retain lifecycle"*0.9 Assume 10 percent of the battery cell is completely degraded
Battery Increase=IF THEN ELSE (Battery-EV Ratio<2, unit increase*4/unit increase time,0)
battery size=500; Units: Kwh
Battery Swapping Station= INTEG (Capacity Increase-Capacity Decrease,Initial number of Station)

Battery-Station ratio=Battery/Battery Swapping Station
Book Value= INTEG (Investment-Depreciation-Disposal,Initial Investment)
Bus Monthly Operating Cost = EBus*Unit Ebus operating cost
Capacity Decrease=Capacity Increase/Average Lifetime of station
Capacity Increase=IF THEN ELSE(Gap in capacity>1, Gap in capacity/station building time, 0)
Cash= INTEG (Cash Inflow-Cash Outflow,0); Units: Dollar
Cash Inflow=Second Life Battery Revenue+Mileage Revenue; Units: Dollar
Cash Outflow=Admin Cost+Car Operating Cost+Station Operation Cost
Contact Rate=0.5
Depreciation=Book Value*Depreciation Rate
Depreciation Rate=0.15
Desired ebus per station=10
Desired User per Unit ebus=25*30
Discount= Annual Gross Revenue*PULSE TRAIN (0,1,12,96)
Discount Rate=0.02; Units: Percent
Discounted FCF=Free Cash Flow/(1+Discount Rate)^Time; Units: Dollar
Disposal=Average Value per eBus*unit decrease+Average Value per Station*Capacity Decrease
EBus= INTEG (unit increase-unit decrease,Initial unit of ebus)
Fixed Asset Turnover Ratio=Annual Gross Revenue/Book Value
Free Cash Flow=Profit-Tax-Investment+Depreciation; Units: Dollar
Gap in capacity=Average ebus per unit station-Desired ebus per station
Gap in Unit=Average User per unit ebus-Desired User per unit ebus

Initial Investment=Initial number of Station*Unit Station Installation Cost+Initial unit of ebus *Unit Bus Purchase Cost; Units: Dollar
Initial number of Station=2
Initial unit of ebus=2
Initial User=20*30
Investment=(Capacity Increase*Unit Station Installation Cost+Unit eBus Purchase Cost*unit increase+Battery Cost*Battery Increase)/Perceived Need to Invest Time Units: Dollar
Investment Thresold= 0
Market=3e06+Battery Swapping Station*100000
Maximum User per Unit ebus=44*30
Mileage Revenue=Revenue per km*Average Mileage*Ebus; Units: Dollar
Perceived Need To Invest Time= 6; Units: Month
Potential Users= INTEG (Return-User Increase,Market+Initial User)
Price of Battery/kWh = 200; Units: Dollar
Price of Second Life Battery=0.3 Unit: Dollar
Profit before Tax= Cash Inflow-Cash Outflow Units: Dollar
Return= IF THEN ELSE (Average User per unit Ebus<Maximum user per unit ebus, 0.5*dissatisfied user*(Maximum user per unit ebus-Average User per unit ebus)/Average User per unit ebus,0) Units: Month
Revenue per km=0.22; Units: Dollar
Second Life Battery= INTEG(Battery Degrade-Decay,0) Units: unit battery

Second Life Battery Revenue= Second Life Battery*Price of Second Battery/kWh*Battery Size; Units:Dollar
Size of Increase= IF THEN ELSE (Gap in Unit>50, IF THEN ELSE (Fixed Asset Turnover Ratio>Investment Threshold, Gap in Unit/10, Gap in Unit/30),0); Units: unit Ebus
Station Building Time= 2+Perceived Need to Invest Time; Units: Month
Station Monthly Operation Cost= Battery Swapping Station* Unit Station Operation Cost; Units: Dollar
Tax= Profit Before Tax*Tax Rate
Tax Rate=0.02; Units:Percent
Unit adjustment time=1.5+Perceived Need To Invest Time; Units: Month
Unit Decrease=unit increase/Average Lifetime of unit vehicle
Unit ebus Operating Cost=12*110*30*0.07; Units: hours x speed x days dollar/km
Unit eBus Purchase cost= 275000; Units: Dollar
Unit increase= Size of Increase/unit adjustment time
Unit Station Installation Cost= 500000; Units: Dollar
Unit Station Operation Cost=500; Units:Dollar
Unsatisfied Rate= IF THEN ELSE(Average User per unit ebus>Maximum user per unit ebus,(Average User per unit ebus)/Average User per unit ebus,0); Units: percent
User Decrease=Unsatisfied Rate*Users/Insatisfaction Perceived Time
User Increase= Potential Users*Contact Rate* Adoption Fraction*Users/Market
Users=INTEG(User Increase-User Decrease,Initial User); Units: people