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Investigating Route Selection by Operators for Optimizing Earning- an Agent Based Modelling Approach

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Abstract

The aim of this study is, to Understanding the levers that can be used to balance the number of informal public transport operators on particular routes with respect to ridership demand and optimized the individual earning and transport network functioning. NetLogo-6.0.2 agent-based modeling is used for exploration of set of rule and presented with an analysis of the combination of probability-to-move for switching the routes and route charges for optimizing earning.

Keywords: Informal public transport network; Agent based modeling, Route operators, pay-off.

1. Introduction

In developing countries, formal public transport network *(FPTN*) operators, and informal public transport network (*IPTN*) operators are two important components of public transport network. In *IPTN*, services are provides by private entities, operating individually or in organization, mostly self-organized. The *IPTN* is a dynamic system that is reacting on all levels of human endeavor and function. Activities related to informal public transport network, when treated in an aggregate way, tend to follow predictable patterns. As *IPTN* are run by private entities, operators mostly concentrated on high ridership demand route. These high ridership demand routes are mostly trunk routes of the city, on which *FPTN* operators also provide their service. Flow of *IPTN* operators along with *FPTN* operators creates a chaos and the congestion on that particular high ridership demand routes, and some average and low ridership demand route face inefficient allocation. This concentration and inefficient allocation of operators also affects the individual earnings.

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A generic model is developed to investigate the route selection by operators for optimizing Earning. In *IPTN,* due to decentralized nature of operation, it is difficult to calculate ridership demand of particular route and actual fleet size running on that route. Heuristic approach is adopted to decide the ridership demand, instead of number of commuters on particular route, total income (payoff) of these routes on a single day is decided. These values are only representative and can be replace with actual data available.

An agent Based Modeling approach adopted for investigation. With the help agent based modeling, particularly "Net-logo" study model was set up, the model is dealing with different patterns that emerge from a dynamics of change originating from the bottom up approach of operators and resulting in aggregate pattern of informal mode operators. The model also deals with the relationship between the elements that comprise these patterns & their dynamics.

2. Concept and set of rules

This model is about three routes, with "high-risk-high-payoff-route", "no-risk-stable-payoff-route" and "low-risk-low-payoff-route". Risk factor on these routes is based on check/monitoring by regional traffic officers to control the illegal activities by operators like exceeding seating capacity to maximize the earning and competition between *FPTN* & *IPTN* operators for commuters. The operator has to select one of the routes for the operation of the vehicle. Operators in this model have access only to pay-off of routes and operators count on particular routes at prior ticks (1 tick = 1 day). Individual operator earning data except personal is inaccessible to other operators.

While designing the rule, two parameters are taken into consideration. First route charges (amount informally paid by the vehicle operator to route operator) and second probability-to-move (percentage of operators are allowed to switch from particular route at single day). The willingness to switch the route is linked with happiness of operators (whether is he happy with prior day earning?). To decide the happiness three simple rules are workout. First, if the earning of "high-risk-high-payoff-route" operators are higher than "no-risk-stable-payoff-route" and "low-risk-low-payoff- route" operator then makes him happy, If not make him unhappy. Second, if the earning of "no-risk-stable-payoff-route" operators are higher than "high-risk-high-payoff-route" and "low-risk-low-payoff-route" operator then makes him happy, If not make him unhappy. And third, if the earning of "low-risk-low-payoff-route" operators are higher than "high-risk-high-payoff-route" and "no-risk-stable-payoff-route" operator then make him happy, If not make him unhappy. Unhappy operator can switch the route for the next day. He can select only that route whose prior day earning is higher than the operator's prior day route.
Let's consider…

a- payoff-high and x- operators count – on, high-risk-high-payoff-route,
b- payoff-stable and y- operators count – on, no-risk-stable-payoff-route,
c- payoff-low and z- operators count – on, low-risk-low-payoff-route.
d- Earning
,

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To Decide-happiness
          For operators-on, high-risk-high-payoff-route
                    set happy if [ ((a / x) > (b / y)) and ((a / x) > (c / z)) ]
          For operators –on,  no-risk-stable-payoff-route
                    set happy if [ ((b / y) > (a / x)) and ((b / y) > (c / z)) ]
          For operators –on,  low-risk-low-payoff-route
                    set happy if  [ ((c / z) > (a / x)) and ((c / z) > (b / y)) ]

To move-turtles-if-unhappy
          For operators on high-risk-high-payoff-route
          Ask n-of ( x * probability-move)
          [     if ((a / x ) < ( b / y )) [ move-to one-of stable-payoff-route set d d - route charges]
                if ((a / x ) < ( c / z )) [ move-to one-of low-payoff-route set d d - route charges]
                if (route charges > d ) [ move-to one-of high-payoff-route ]  ]
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For operators on no-risk-stable-payoff-route
Ask n-of ( y * probability-move)
[    if (( b / y ) < ( a / x )) [ move-to one-of high-payoff-route set d d - route charges]
     if (( b / y ) < ( c / z )) [ move-to one-of low-payoff-route set d d - route charges]
     if (route charges > d ) [ move-to one-of stable-payoff-route ]  ]
For operators on low-risk-low-payoff-route
Ask n-of ( z * probability-move)
[    if (( c / z ) < ( a / x )) [ move-to one-of high-payoff-route set d d - route charges]
     if (( c / z ) < ( b / y )) [ move-to one-of stable-payoff-route set d d - route charges]
     if (route charges > d ) [ move-to one-of low-payoff-route ]  ]
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But if all unhappy operators switch to prior day higher earning route, can be result in overcrowding and overall reduction in earning of operators of that route. To avoid this probability-to-move slider is used to control the percentage of operators are allowed to switch from particular route at single day. Along with the probability-to-move, route charges - amount informally paid by the vehicle operator to route operator to switch the route is also used to discourage the route-switching.

3. Setting up Model

NetLogo-6.0.2 agent-based modeling is used for setting up the model. Three patches representing “high-risk-high-payoff-route”, “no-risk-stable-payoff-route” and “low-risk-low-payoff-route” were set up first with payoff probability. The “high-risk-high-payoff-route” pays d = 80 units (split evenly among the operators of the route) with probability 0.25 and d = 0 unit otherwise (0.75 probability), any operator that locates at the “no-risk-stable-payoff-route” always receives d = 1 unit at the end of the day-tick and the “low-risk-low-payoff-route” pays d = 40 units (split evenly among the operators) with probability 0.5 and d = 0 unit otherwise (0.5 probability). At first operators is set-up and placed randomly at any of the routes, with the help of go button model run for 100 ticks. Payoff for each route will be generated and split into number of operators equally. Based on unhappy operators and probability-to-move operators keep on switching throughout the run. “d”- earning of individual operators, operators count on all routes and the payoff of each route for the day is recorded with the help of plot and monitors.

4. Testing

Different combination of Probability-to-move ranging from 0.25 to 0.75 with the interval of 0.1, route charges- ranging from 1 to 3 with the interval of 1 and total vehicular operator counts (50 & 100) on all routes are tested separately with the help of “Behavior-space” in the Net-Logo model for generating the data output. The Model is run up-to 100 ticks, each combination of probability-to-move and route charges to repeat for 3 times separately for 50 vehicular operators and 100 vehicular operators. Operators count and payoff for “high-risk-high-payoff-route”, “no-risk-stable-payoff-route” and “low-risk-low-payoff-route” is recorded for each tick. Also earning of each operator is recorded for each tick. Average values of 3 runs for one combination of probability-to-move and route charges (ex. - Probability-to-move 0.25 and route charges 3) are taken into consideration for analysis purpose. Random 5 operators, data are analyzed for individual and aggregate level behavior in this system. Initial, maximum and final operators count on each route for 100 ticks with all Probability-to-move ranging from 0.25 to 0.75 are analyzed for system behavior. The Effect of changing the route charges on earning pattern is also analyzed with same experiment.

5. Observation and Analysis

With operators count 50 and route charges 1 unit combination (Table -1 & fig.-2, 3) earning of the individual as well as aggregate level tend to be on the higher side, decreases with route charges value 3 units. Optimal number of operators leads to better earning at individual as well as aggregate level (Table -1). Increase in route charges value affect the earning pattern, operators keep on switching the route and earn nothing leads to negative debt, clearly visible from chart with both 50 and 100 operators count and route charges-3 unit (Table -1 & fig.-1,2). In selected 5 operators, when probability-to-move increases above 0.55 individuals as well as aggregate level earning also get reduced, except in one case where probability-to-move 0.75 and route charges 3 unit combination mark high earning value (fig.-1,2). Probability-to-move ranging from 0.25 to 0.45 marked higher earnings in most of the cases (fig.- 1,2). With route charges 1 unit, maximum and final value of operators counts are almost same, however descending trend is observed with route charges equal to 2 & 3 units (fig.-1, 2). With route charges 2 units and probability-to-move 0.75 in most cases final earning is lower than max earning. With route charges 3 units, a decrease in the mean and max earning is observed as compared to final earning. If final earning value is lesser than mean and max earning, the operator is in loss. If final earning value is higher than the mean and max earning, operator earns better.

Maximum operators count, at any time step out of 100 at all probability-to-move and route charges combination observed at no-risk stable-payoff route (Table -2 & fig.-2). With the value of route charges 1 & 2 units, maximum number of operators chooses no-risk stable-payoff-route at the end of 100 ticks (fig.-4). Operators count on high-risk-high-payoff-route is very low at the end of 100 time steps as compared to no-risk-stable-payoff-route and low-risk-low-payoff route (fig.-4). In a few cases the maximum number of operator counts at 100 time steps observed on low-risk- low-payoff route (fig.-4). With probability-to-move 0.75 and route charges 3 units, operators count observed higher in high-risk high-payoff route. The overall operator counts on high-risk-high-payoff route is low, whenever there is a payoff- slightly increase in operators count is observed (fig.-3). High risk in term of competition within *IPTN* and availability of *FPTN* can be the one of reason of low operators count on high-risk-high-payoff route. Operators count on low-risk-low-payoff route is in sync payoff of prior day tick (fig.-3).

6. Conclusion

This model is helpful in understanding the levers that can be used to balance the number of informal public transport operators on particular routes with respect to ridership demand and optimized the individual earning and transport network functioning. Not only in *IPTN* but fleet size of *FPTN* operators can be possible to calculate with some modification in model with respect to capacity of mode and frequency on particular route.

Table 1: chart of the earning range of operators, from figure 1 & 2.

Operators	Operators count -50				Operators count -100		
	route charges-1	route charges-2	route charges-3		route charges-1	route charges-2	route charges-3
Operator-0	0 to 140 d	-40 to 100 d	-100 to 80 d		-10 to 70 d	-40 to 60 d	-10 to 80 d
Operator -1	0 to 120 d	-20 to 120 d	-40 to 120 d		-10 to 70 d	-60 to 80 d	-120 to 60 d
Operator -2	0 to 160 d	-20 to 100 d	-80 to 60 d		-20 to 100 d	-20 to 60 d	-100 to 60 d
Operator -3	0 to 140 d	-20 to 100 d	-80 to 80 d		-10 to 80 d	-10 to 60 d	-120 to 60 d
Operator -4	0 to 120 d	0 to 140 d	-150 to 100 d		-20 to 100 d	-30 to 70 d	-120 to 40 d
Probability-to-move - 0.25 0.35 0.45 0.55 0.65 0.75							

Table 2: chart of operators count on- high-risk-high-payoff-route, no-risk-stable-payoff-route and low-risk-low-payoff-route from figure 4.

Operator on	route charges-1			route charges-2			route charges-3		
	initial	max	final	initial	max	final	initial	max	final
High risk-high-payoff route	5 to 30	20 to 50	0 to 15	5 to 20	20 to 50	0 to 20	5 to 20	20 to 50	0 to 15
No risk-stable-payoff route	5 to 30	30 to 50	15 to 25	5 to 25	35 to 50	15 to 30	0 to 30	35 to 50	5 to 25
Low risk-low-payoff route	10 to 30	30 to 50	15 to 35	5 to 30	35 to 50	10 to 25	15 to 35	35 to 50	15 to 30
Probability-move - 0.25 0.35 0.45 0.55 0.65 0.75									

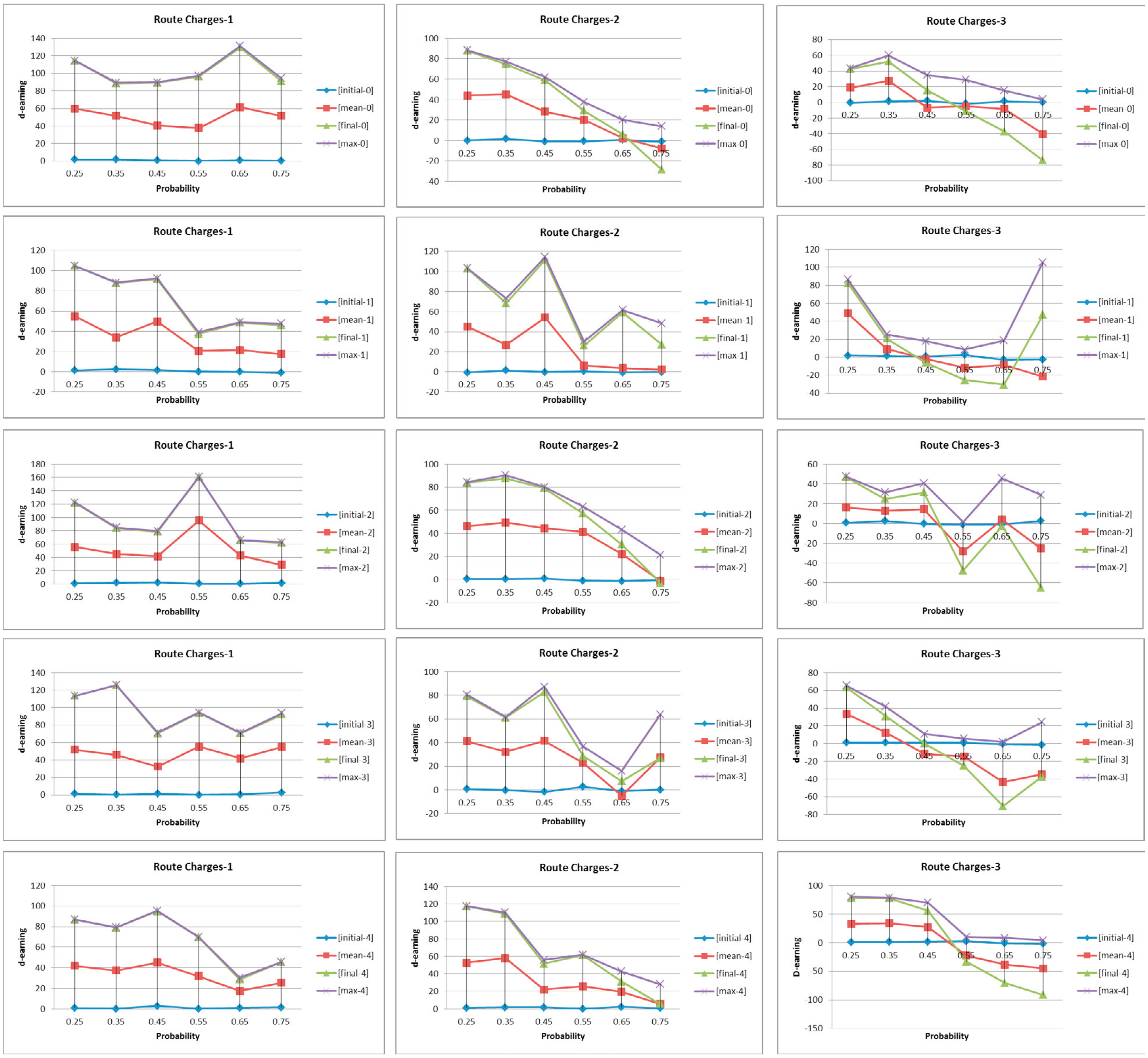

Figure 1 Selected five operators earning, total operators count -50 (0, 1, 2, 3 & 4 stand for operator number)

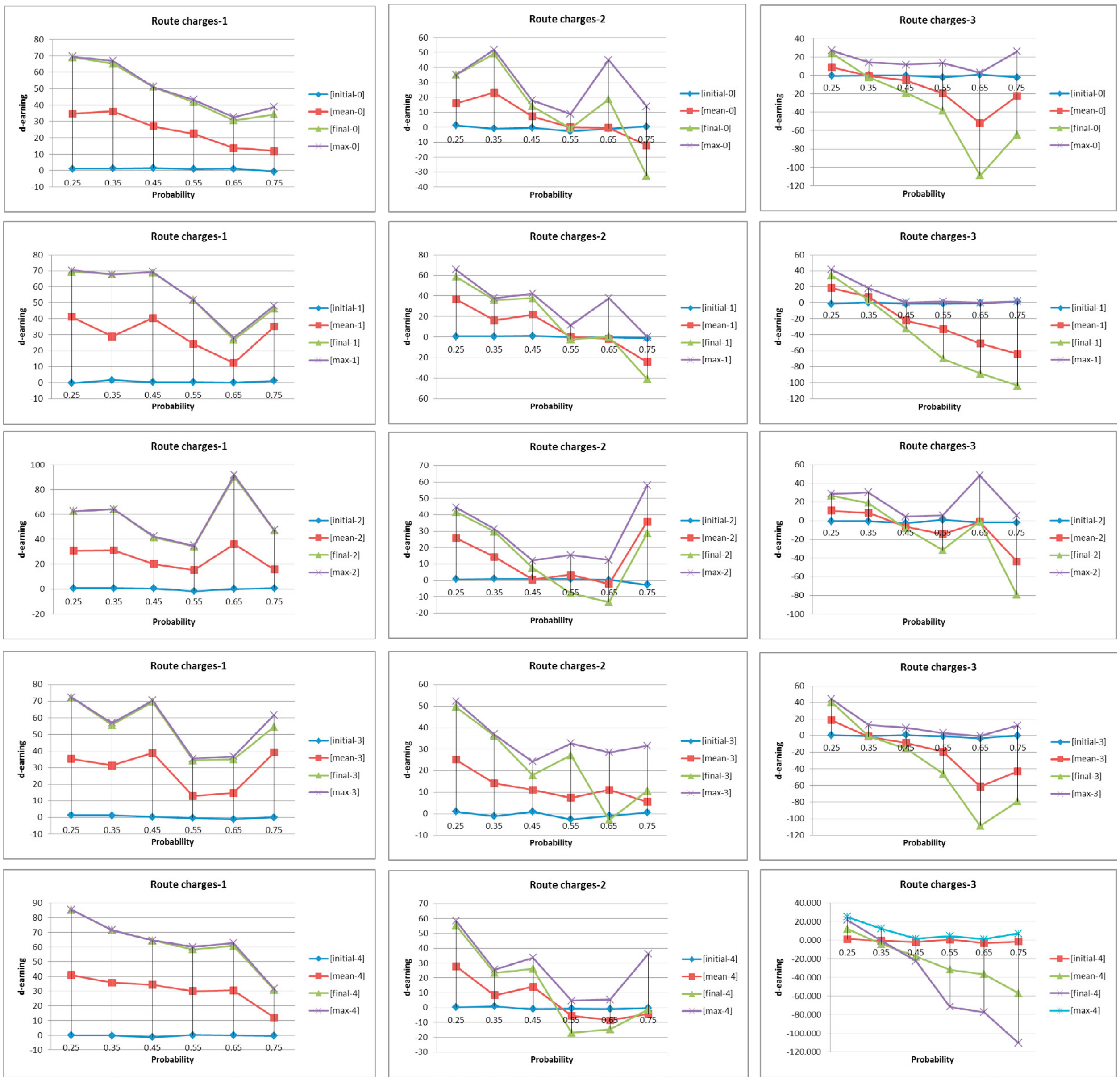

Figure 2 Selected five operators earning, total operators count -100 (0, 1, 2, 3 & 4 stand for operator number)

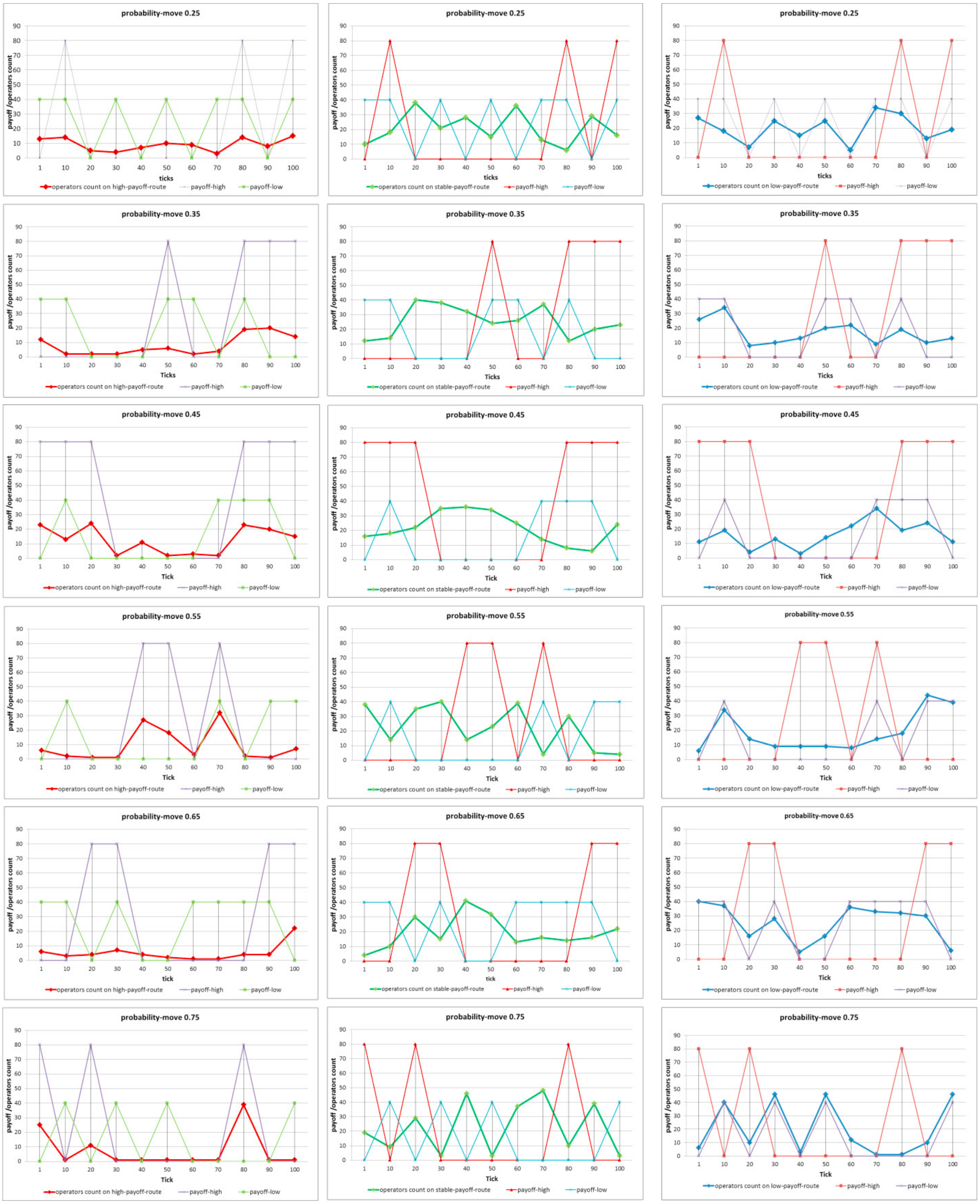

Figure 3 Route payoff and Operators count chart

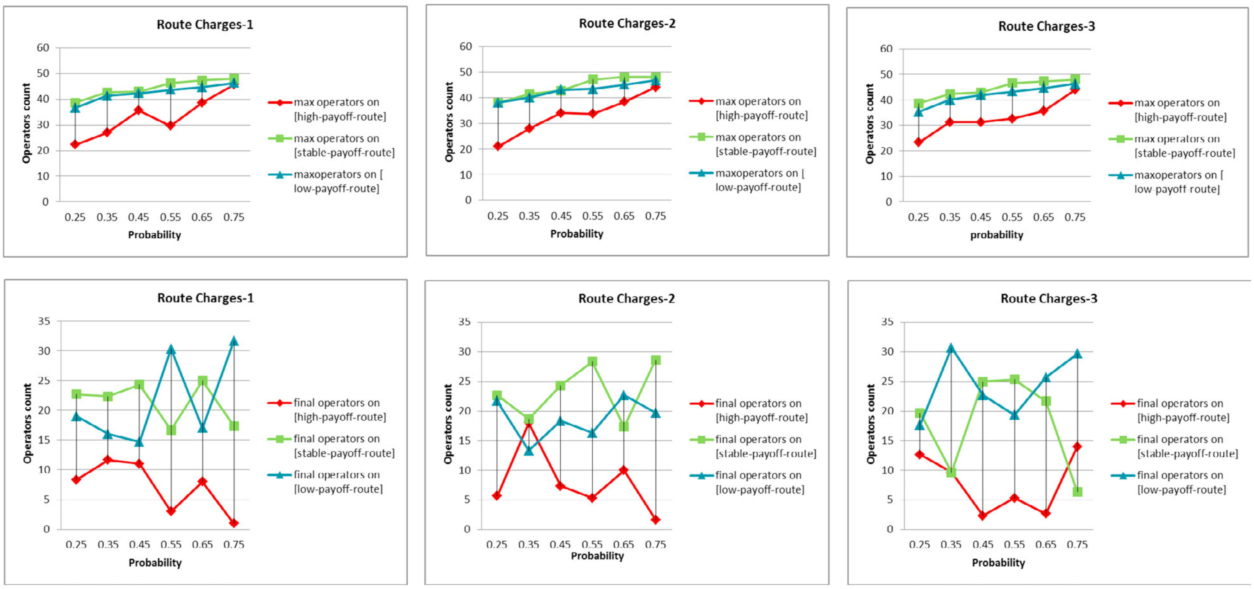

*Figure 4 M*ax-final operators count on high-risk-high-payoff-route, no-risk-stable-payoff-route and low-risk-low-payoff route.

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