Assignment 3

1. Create an informed mutation operator and compare the results with those from last time.
2. Write a short text about what you tried, how it worked and submit a plot showing the difference.

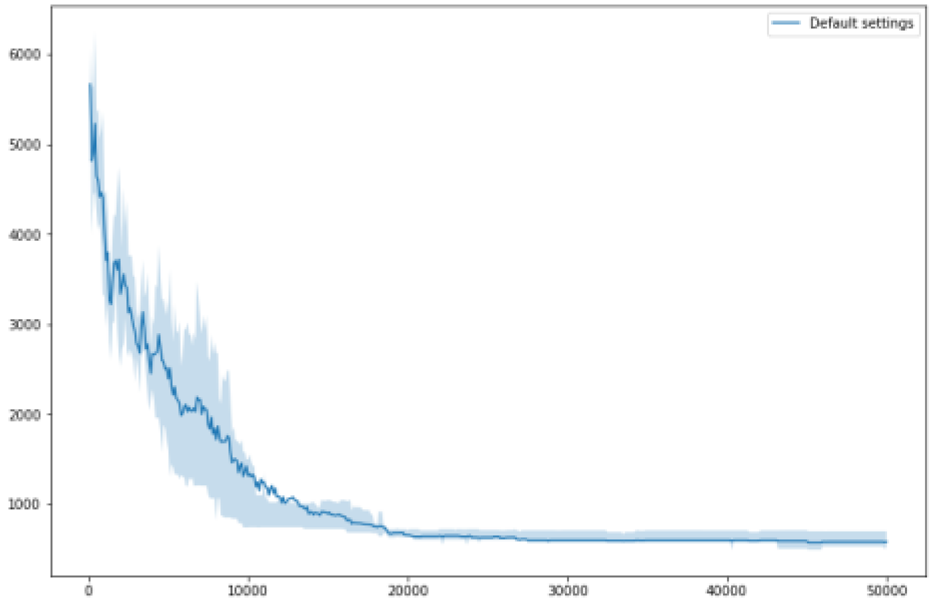
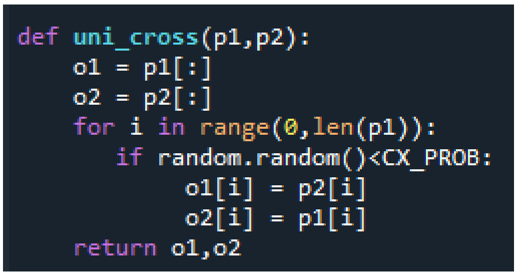


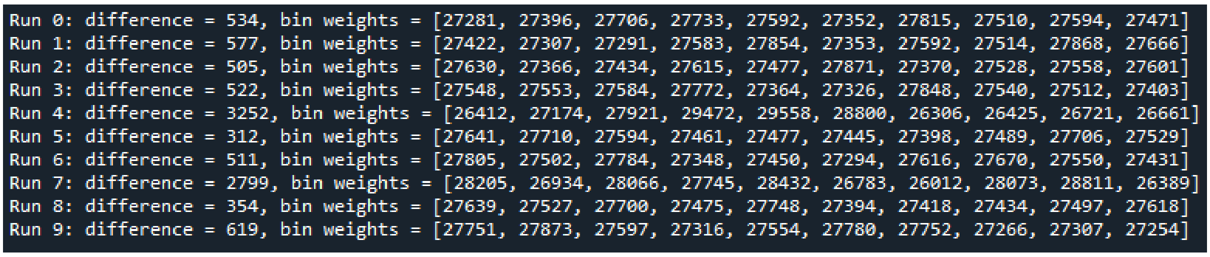
Fig: Output without any alteration in the code.

a) Modifying the crossover operator to uniform crossover without altering rest of code.

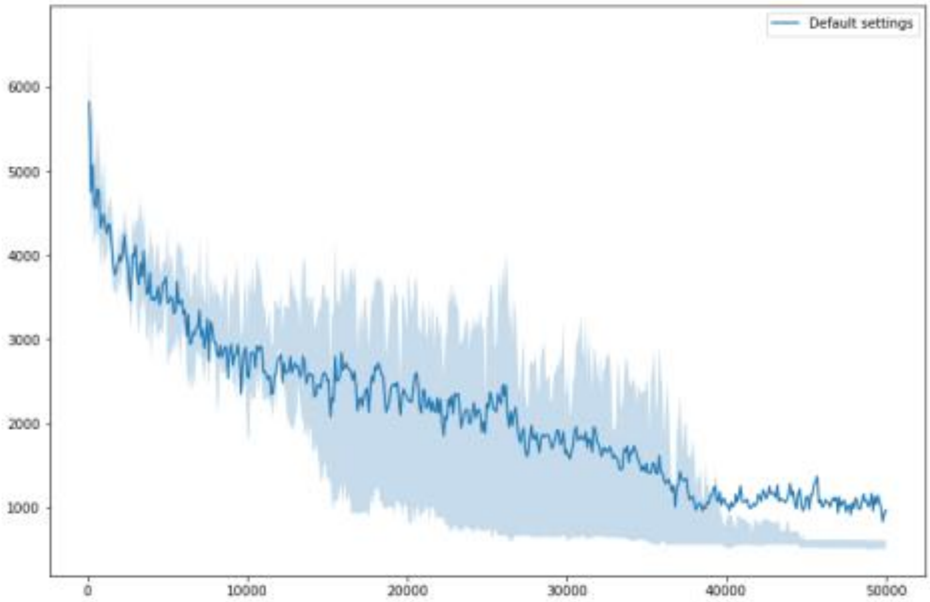


```
def uni_cross(p1,p2):
    o1 = p1[:]
    o2 = p2[:]
    for i in range(0,len(p1)):
       if random.random()<CX_PROB:
            o1[i] = p2[i]
            o2[i] = p1[i]
    return o1,o2
```

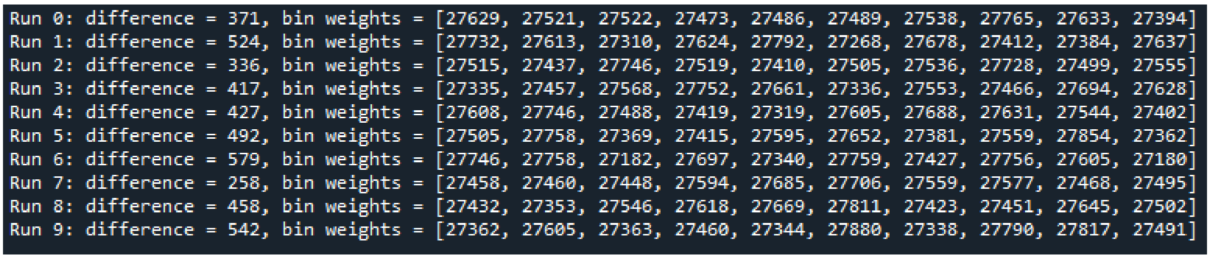
With Crossover probability of 90%.



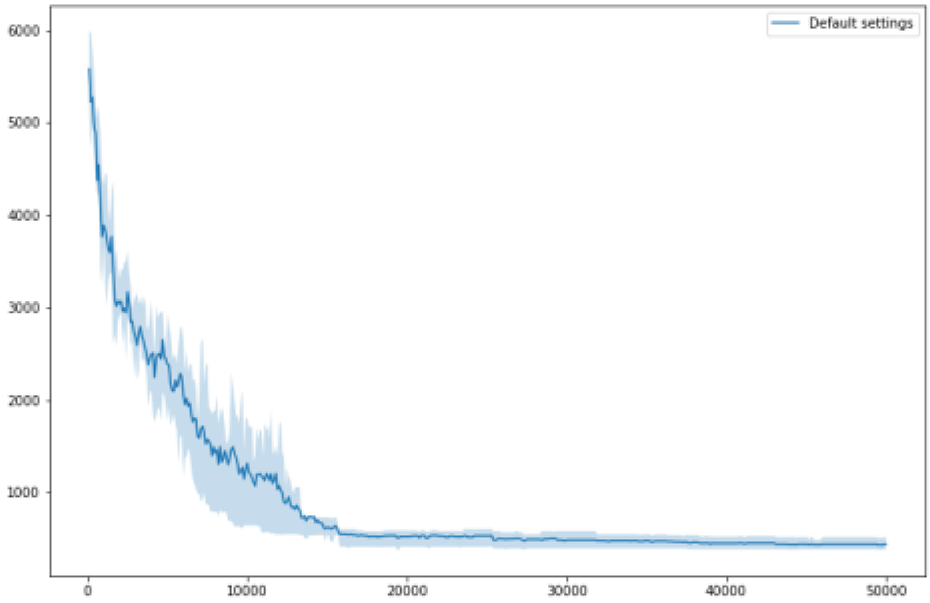
```
Run 0: difference = 534, bin weights = [27281, 27396, 27706, 27733, 27592, 27352, 27815, 27510, 27594, 27471]
Run 1: difference = 577, bin weights = [27422, 27307, 27291, 27583, 27854, 27353, 27592, 27514, 27868, 27666]
Run 2: difference = 505, bin weights = [27630, 27366, 27434, 27615, 27477, 27871, 27370, 27528, 27558, 27601]
Run 3: difference = 522, bin weights = [27548, 27553, 27584, 27772, 27364, 27326, 27848, 27540, 27512, 27403]
Run 4: difference = 3252, bin weights = [26412, 27174, 27921, 29472, 29558, 28800, 26306, 26425, 26721, 26661]
Run 5: difference = 312, bin weights = [27641, 27710, 27594, 27461, 27477, 27445, 27398, 27489, 27706, 27529]
Run 6: difference = 511, bin weights = [27805, 27502, 27784, 27348, 27450, 27294, 27616, 27670, 27550, 27431]
Run 7: difference = 2799, bin weights = [28205, 26934, 28066, 27745, 28432, 26783, 26012, 28073, 28811, 26389]
Run 8: difference = 354, bin weights = [27639, 27527, 27700, 27475, 27748, 27394, 27418, 27434, 27497, 27618]
Run 9: difference = 619, bin weights = [27751, 27873, 27597, 27316, 27554, 27780, 27752, 27266, 27307, 27254]
```



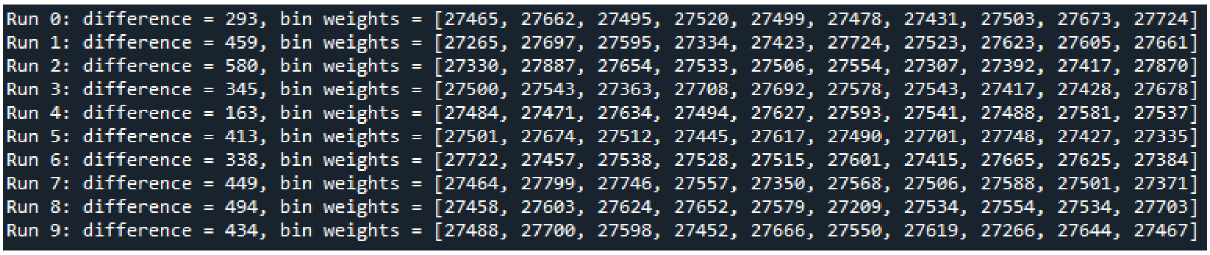
With Crossover probability of 95%.



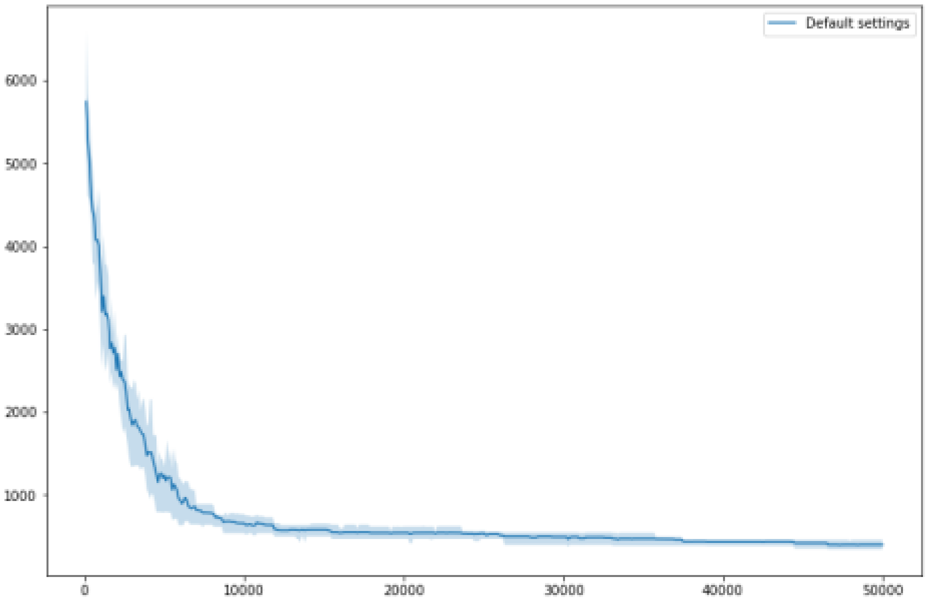
```
Run 0: difference = 371, bin weights = [27629, 27521, 27522, 27473, 27486, 27489, 27538, 27765, 27633, 27394]
Run 1: difference = 524, bin weights = [27732, 27613, 27310, 27624, 27792, 27268, 27678, 27412, 27384, 27637]
Run 2: difference = 336, bin weights = [27515, 27437, 27746, 27519, 27410, 27505, 27536, 27728, 27499, 27555]
Run 3: difference = 417, bin weights = [27335, 27457, 27568, 27752, 27661, 27336, 27553, 27466, 27694, 27628]
Run 4: difference = 427, bin weights = [27608, 27746, 27488, 27419, 27319, 27605, 27688, 27631, 27544, 27402]
Run 5: difference = 492, bin weights = [27505, 27758, 27369, 27415, 27595, 27652, 27381, 27559, 27854, 27362]
Run 6: difference = 579, bin weights = [27746, 27758, 27182, 27697, 27340, 27759, 27427, 27756, 27605, 27180]
Run 7: difference = 258, bin weights = [27458, 27460, 27448, 27594, 27685, 27706, 27559, 27577, 27468, 27495]
Run 8: difference = 458, bin weights = [27432, 27353, 27546, 27618, 27669, 27811, 27423, 27451, 27645, 27502]
Run 9: difference = 542, bin weights = [27362, 27605, 27363, 27460, 27344, 27880, 27338, 27790, 27817, 27491]
```



After multiple runs, the least difference value obtained with uniform crossover was 163 with Crossover probability at 97%.

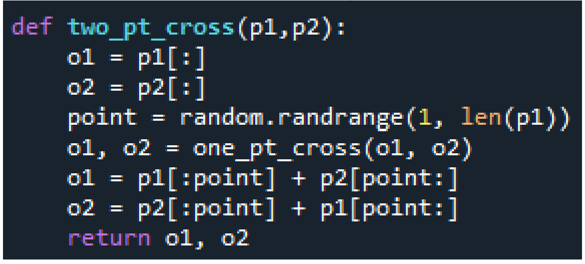


```
Run 0: difference = 293, bin weights = [27465, 27662, 27495, 27520, 27499, 27478, 27431, 27503, 27673, 27724]
Run 1: difference = 459, bin weights = [27265, 27697, 27595, 27334, 27423, 27724, 27523, 27623, 27605, 27661]
Run 2: difference = 580, bin weights = [27330, 27887, 27654, 27533, 27506, 27554, 27307, 27392, 27417, 27870]
Run 3: difference = 345, bin weights = [27500, 27543, 27363, 27708, 27692, 27578, 27543, 27417, 27428, 27678]
Run 4: difference = 163, bin weights = [27484, 27471, 27634, 27494, 27627, 27593, 27541, 27488, 27581, 27537]
Run 5: difference = 413, bin weights = [27501, 27674, 27512, 27445, 27617, 27490, 27701, 27748, 27427, 27335]
Run 6: difference = 338, bin weights = [27722, 27457, 27538, 27528, 27515, 27601, 27415, 27665, 27625, 27384]
Run 7: difference = 449, bin weights = [27464, 27799, 27746, 27557, 27350, 27568, 27506, 27588, 27501, 27371]
Run 8: difference = 494, bin weights = [27458, 27603, 27624, 27652, 27579, 27209, 27534, 27554, 27534, 27703]
Run 9: difference = 434, bin weights = [27488, 27700, 27598, 27452, 27666, 27550, 27619, 27266, 27644, 27467]
```

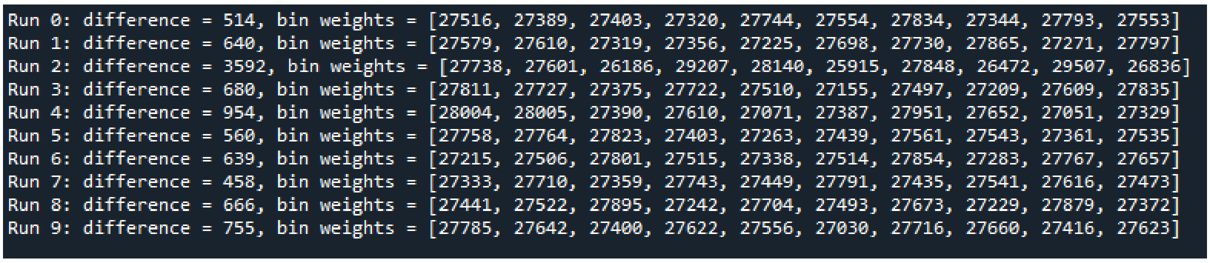


b) Modifying the crossover operator to two point crossover without altering rest of code.

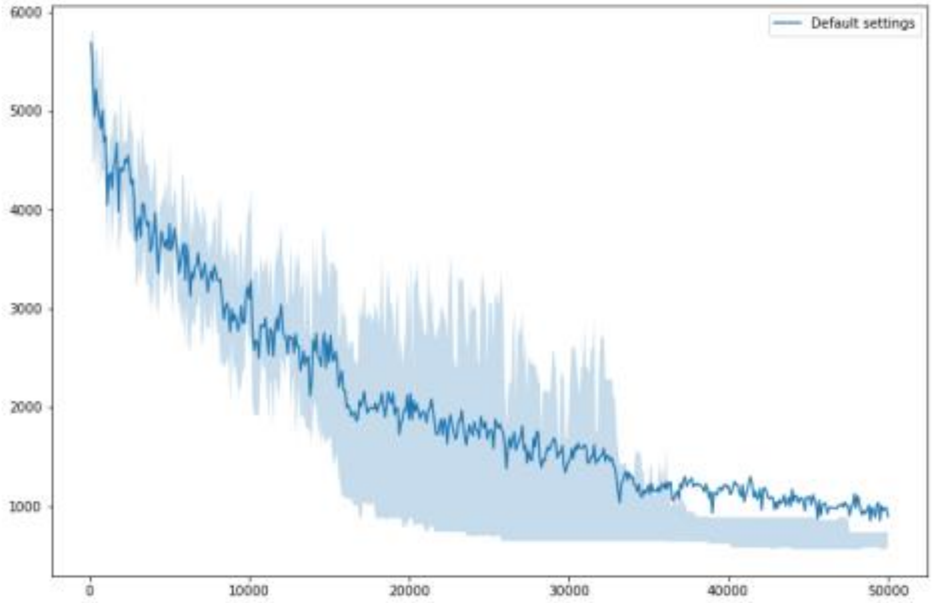
With Crossover probability of 90%.



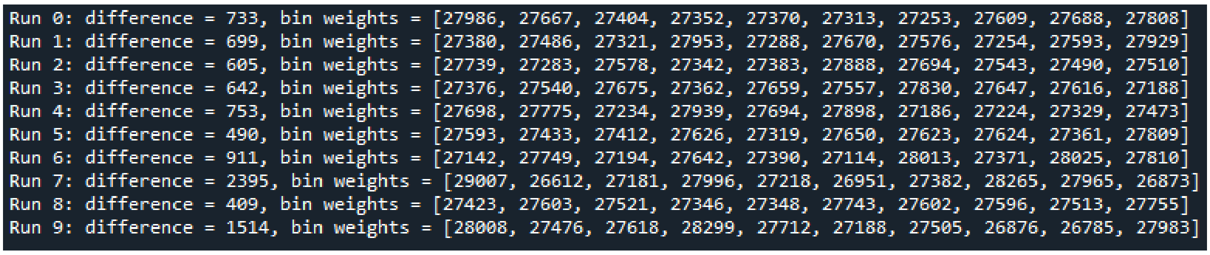
```
def two_pt_cross(p1,p2):
    o1 = p1[:]
    o2 = p2[:]
    point = random.randrange(1, len(p1))
    o1, o2 = one_pt_cross(o1, o2)
    o1 = p1[:point] + p2[point:]
    o2 = p2[:point] + p1[point:]
    return o1, o2
```



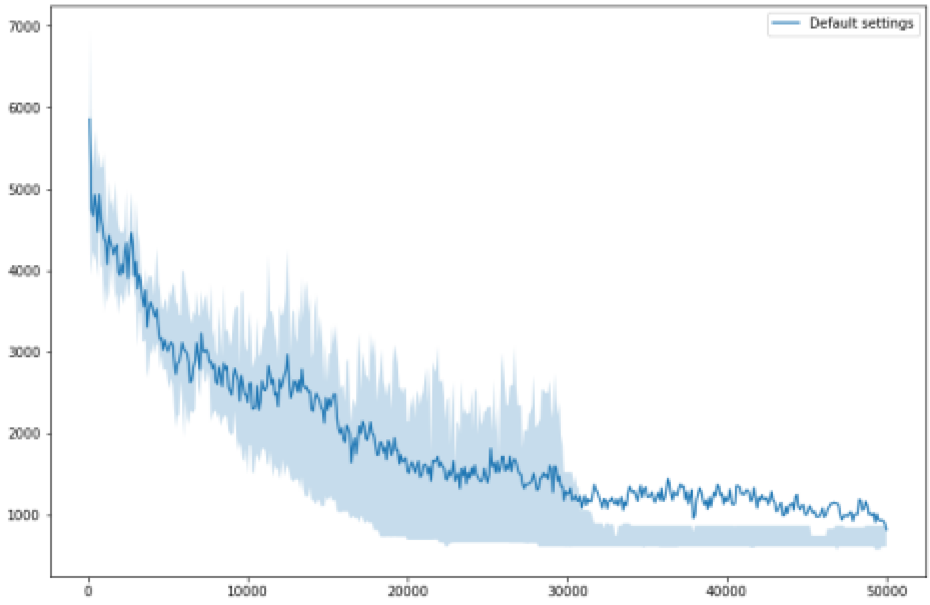
```
Run 0: difference = 514, bin weights = [27516, 27389, 27403, 27320, 27744, 27554, 27834, 27344, 27793, 27553]
Run 1: difference = 640, bin weights = [27579, 27610, 27319, 27356, 27225, 27698, 27730, 27865, 27271, 27797]
Run 2: difference = 3592, bin weights = [27738, 27601, 26186, 29207, 28140, 25915, 27848, 26472, 29507, 26836]
Run 3: difference = 680, bin weights = [27811, 27727, 27375, 27722, 27510, 27155, 27497, 27209, 27609, 27835]
Run 4: difference = 954, bin weights = [28004, 28005, 27390, 27610, 27071, 27387, 27951, 27652, 27051, 27329]
Run 5: difference = 560, bin weights = [27758, 27764, 27823, 27403, 27263, 27439, 27561, 27543, 27361, 27535]
Run 6: difference = 639, bin weights = [27215, 27506, 27801, 27515, 27338, 27514, 27854, 27283, 27767, 27657]
Run 7: difference = 458, bin weights = [27333, 27710, 27359, 27743, 27449, 27791, 27435, 27541, 27616, 27473]
Run 8: difference = 666, bin weights = [27441, 27522, 27895, 27242, 27704, 27493, 27673, 27229, 27879, 27372]
Run 9: difference = 755, bin weights = [27785, 27642, 27400, 27622, 27556, 27030, 27716, 27660, 27416, 27623]
```



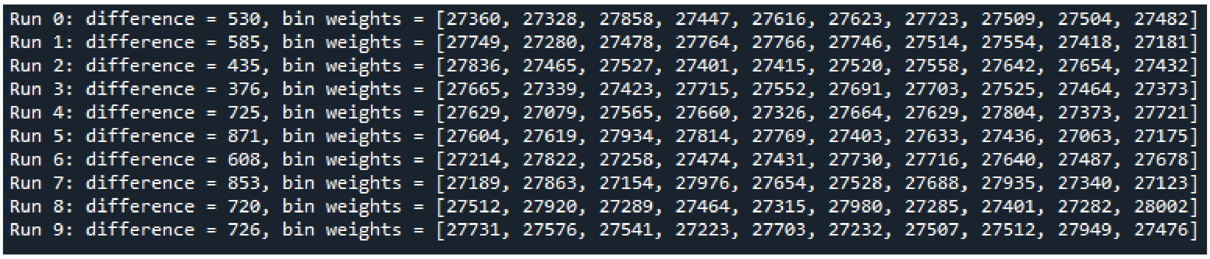
After multiple runs, the least difference value obtained with uniform crossover was 409 with Crossover probability at 90%.



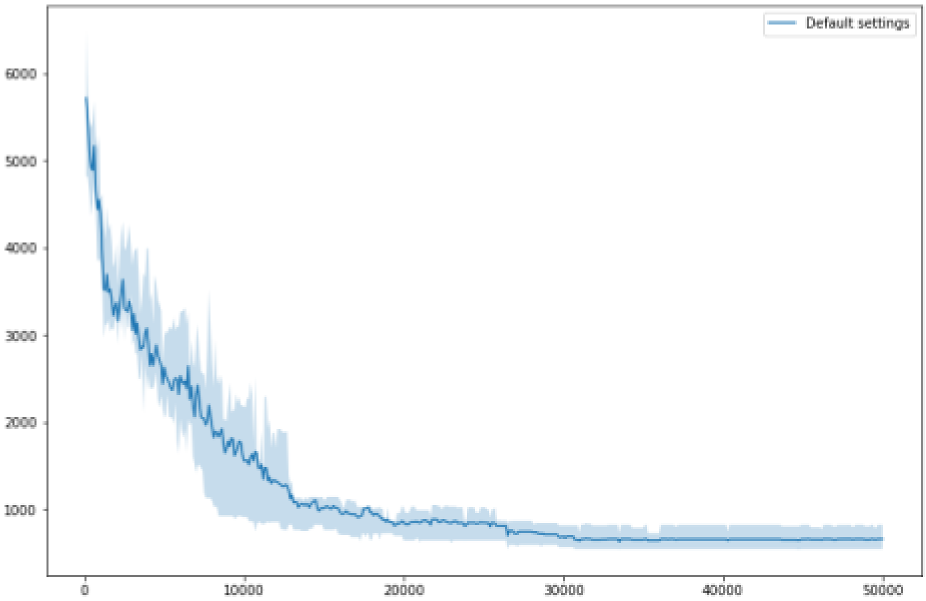
```
Run 0: difference = 733, bin weights = [27986, 27667, 27404, 27352, 27370, 27313, 27253, 27609, 27688, 27808]
Run 1: difference = 699, bin weights = [27380, 27486, 27321, 27953, 27288, 27670, 27576, 27254, 27593, 27929]
Run 2: difference = 605, bin weights = [27739, 27283, 27578, 27342, 27383, 27888, 27694, 27543, 27490, 27510]
Run 3: difference = 642, bin weights = [27376, 27540, 27675, 27362, 27659, 27557, 27830, 27647, 27616, 27188]
Run 4: difference = 753, bin weights = [27698, 27775, 27234, 27939, 27694, 27898, 27186, 27224, 27329, 27473]
Run 5: difference = 490, bin weights = [27593, 27433, 27412, 27626, 27319, 27650, 27623, 27624, 27361, 27809]
Run 6: difference = 911, bin weights = [27142, 27749, 27194, 27642, 27390, 27114, 28013, 27371, 28025, 27810]
Run 7: difference = 2395, bin weights = [29007, 26612, 27181, 27996, 27218, 26951, 27382, 28265, 27965, 26873]
Run 8: difference = 409, bin weights = [27423, 27603, 27521, 27346, 27348, 27743, 27602, 27596, 27513, 27755]
Run 9: difference = 1514, bin weights = [28008, 27476, 27618, 28299, 27712, 27188, 27505, 26876, 26785, 27983]
```



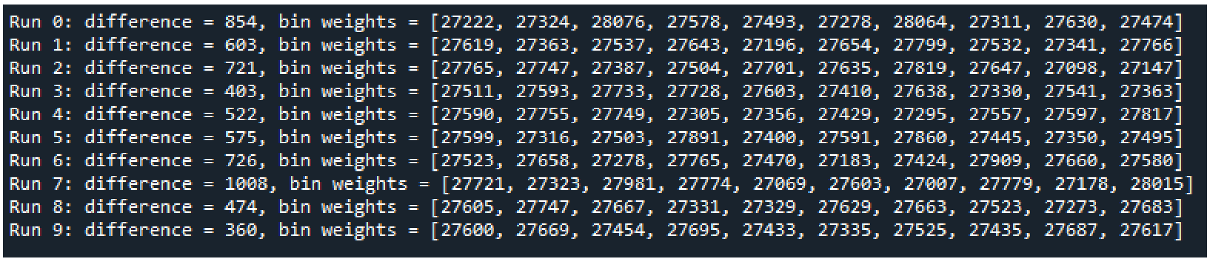
With Crossover probability of 80%.



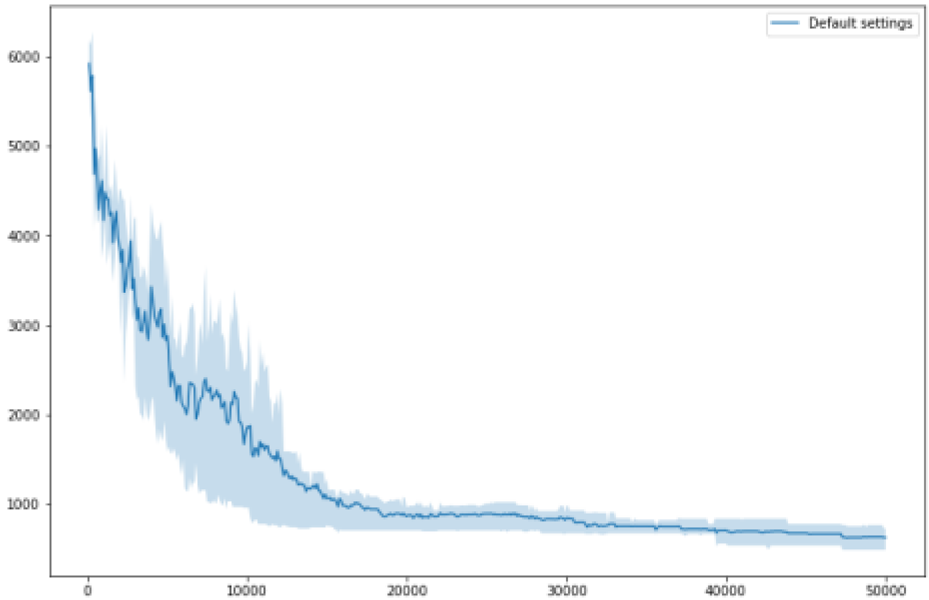
```
Run 0: difference = 530, bin weights = [27360, 27328, 27858, 27447, 27616, 27623, 27723, 27509, 27504, 27482]
Run 1: difference = 585, bin weights = [27749, 27280, 27478, 27764, 27766, 27746, 27514, 27554, 27418, 27181]
Run 2: difference = 435, bin weights = [27836, 27465, 27527, 27401, 27415, 27520, 27558, 27642, 27654, 27432]
Run 3: difference = 376, bin weights = [27665, 27339, 27423, 27715, 27552, 27691, 27703, 27525, 27464, 27373]
Run 4: difference = 725, bin weights = [27629, 27079, 27565, 27660, 27326, 27664, 27629, 27804, 27373, 27721]
Run 5: difference = 871, bin weights = [27604, 27619, 27934, 27814, 27769, 27403, 27633, 27436, 27063, 27175]
Run 6: difference = 608, bin weights = [27214, 27822, 27258, 27474, 27431, 27730, 27716, 27640, 27487, 27678]
Run 7: difference = 853, bin weights = [27189, 27863, 27154, 27976, 27654, 27528, 27688, 27935, 27340, 27123]
Run 8: difference = 720, bin weights = [27512, 27920, 27289, 27464, 27315, 27980, 27285, 27401, 27282, 28002]
Run 9: difference = 726, bin weights = [27731, 27576, 27541, 27223, 27703, 27232, 27507, 27512, 27949, 27476]
```



After multiple runs, the least difference value obtained with uniform crossover was 409 with Crossover probability at 80%.

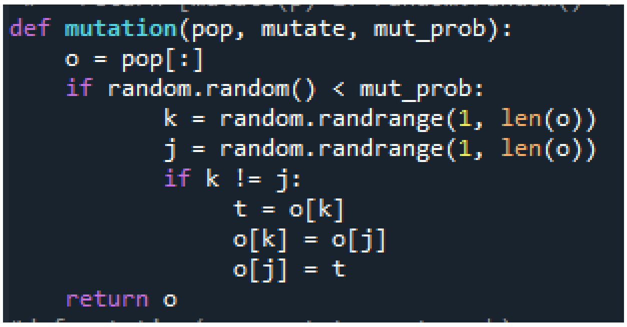


```
Run 0: difference = 854, bin weights = [27222, 27324, 28076, 27578, 27493, 27278, 28064, 27311, 27630, 27474]
Run 1: difference = 603, bin weights = [27619, 27363, 27537, 27643, 27196, 27654, 27799, 27532, 27341, 27766]
Run 2: difference = 721, bin weights = [27765, 27747, 27387, 27504, 27701, 27635, 27819, 27647, 27098, 27147]
Run 3: difference = 403, bin weights = [27511, 27593, 27733, 27728, 27603, 27410, 27638, 27330, 27541, 27363]
Run 4: difference = 522, bin weights = [27590, 27755, 27749, 27305, 27356, 27429, 27295, 27557, 27597, 27817]
Run 5: difference = 575, bin weights = [27599, 27316, 27503, 27891, 27400, 27591, 27860, 27445, 27350, 27495]
Run 6: difference = 726, bin weights = [27523, 27658, 27278, 27765, 27470, 27183, 27424, 27909, 27660, 27580]
Run 7: difference = 1008, bin weights = [27721, 27323, 27981, 27774, 27069, 27603, 27007, 27779, 27178, 28015]
Run 8: difference = 474, bin weights = [27605, 27747, 27667, 27331, 27329, 27629, 27663, 27523, 27273, 27683]
Run 9: difference = 360, bin weights = [27600, 27669, 27454, 27695, 27433, 27335, 27525, 27435, 27687, 27617]
```



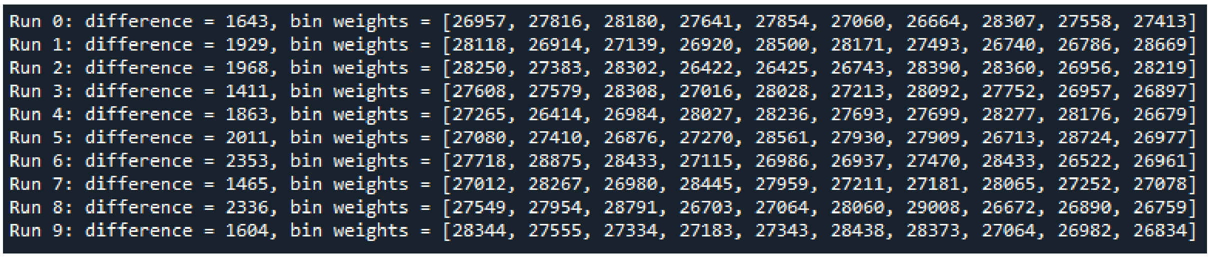
From my experiments, Uniform crossover resulted better performance than two-point crossover.

c) Mutation, which swaps parts of the encoding inside the individual.

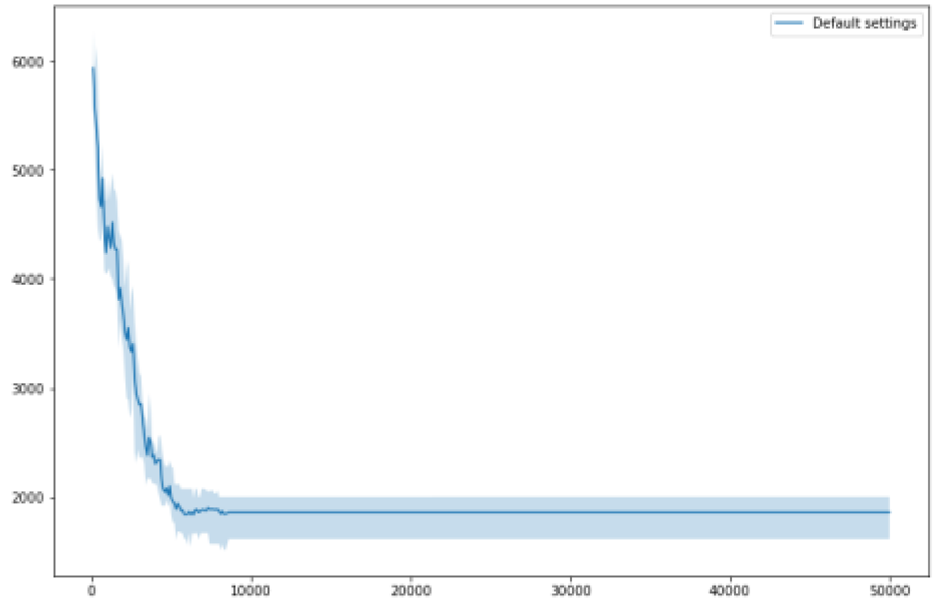


```
def mutation(pop, mutate, mut_prob):
    o = pop[:]
    if random.random() < mut_prob:
           k = random.randrange(1, len(o))
           j = random.randrange(1, len(o))
           if k != j:
                t = o[k]
                o[k] = o[j]
                o[j] = t
    return o
```

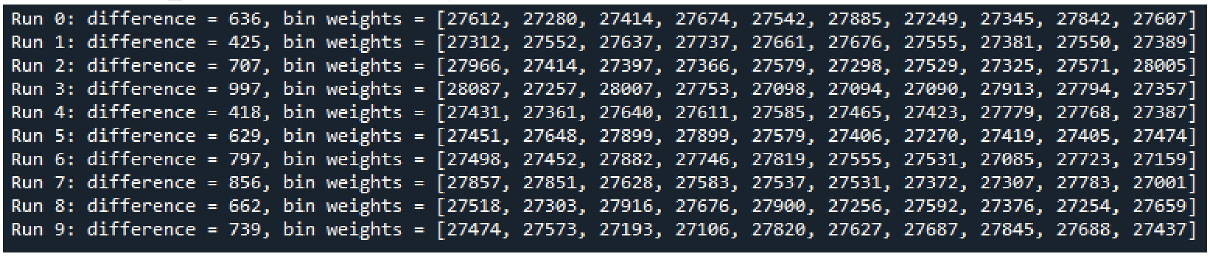
With one_pt_cross & mutation prob at 20%.



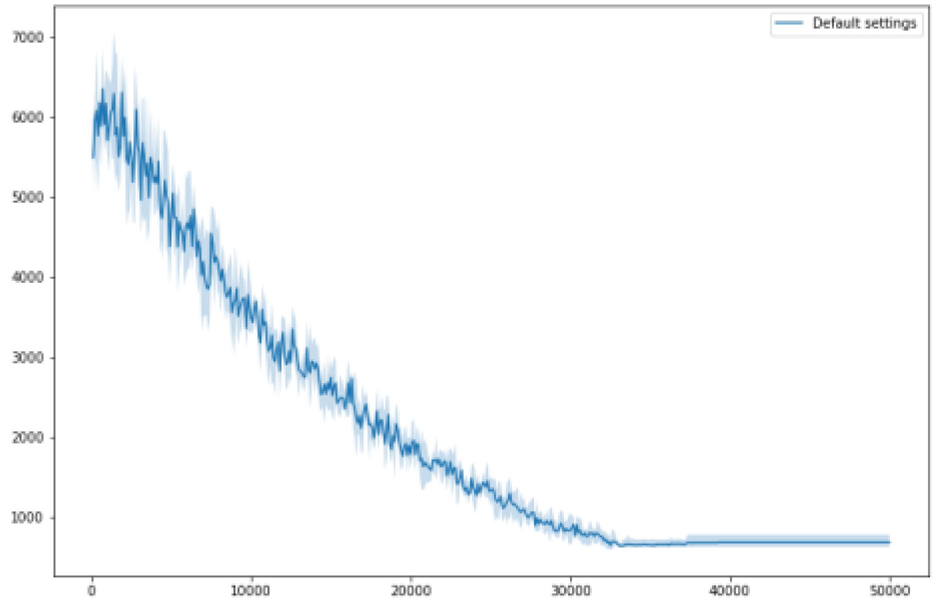
```
Run 0: difference = 1643, bin weights = [26957, 27816, 28180, 27641, 27854, 27060, 26664, 28307, 27558, 27413]
Run 1: difference = 1929, bin weights = [28118, 26914, 27139, 26920, 28500, 28171, 27493, 26740, 26786, 28669]
Run 2: difference = 1968, bin weights = [28250, 27383, 28302, 26422, 26425, 26743, 28390, 28360, 26956, 28219]
Run 3: difference = 1411, bin weights = [27608, 27579, 28308, 27016, 28028, 27213, 28092, 27752, 26957, 26897]
Run 4: difference = 1863, bin weights = [27265, 26414, 26984, 28027, 28236, 27693, 27699, 28277, 28176, 26679]
Run 5: difference = 2011, bin weights = [27080, 27410, 26876, 27270, 28561, 27930, 27909, 26713, 28724, 26977]
Run 6: difference = 2353, bin weights = [27718, 28875, 28433, 27115, 26986, 26937, 27470, 28433, 26522, 26961]
Run 7: difference = 1465, bin weights = [27012, 28267, 26980, 28445, 27959, 27211, 27181, 28065, 27252, 27078]
Run 8: difference = 2336, bin weights = [27549, 27954, 28791, 26703, 27064, 28060, 29008, 26672, 26890, 26759]
Run 9: difference = 1604, bin weights = [28344, 27555, 27334, 27183, 27343, 28438, 28373, 27064, 26982, 26834]
```



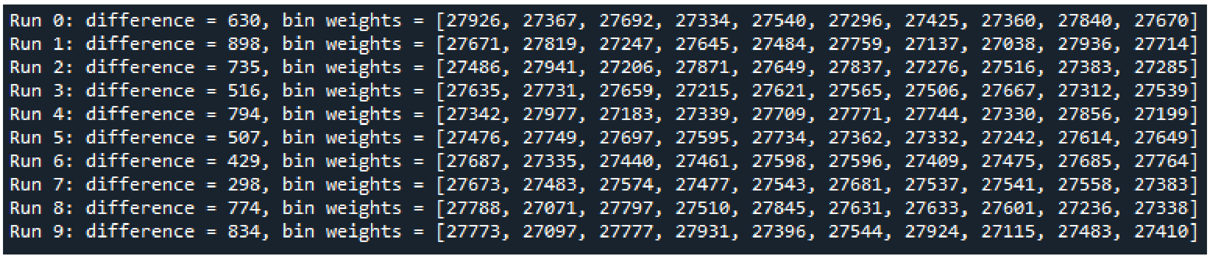
With Uniform_crossover & mutation prob at 20%.



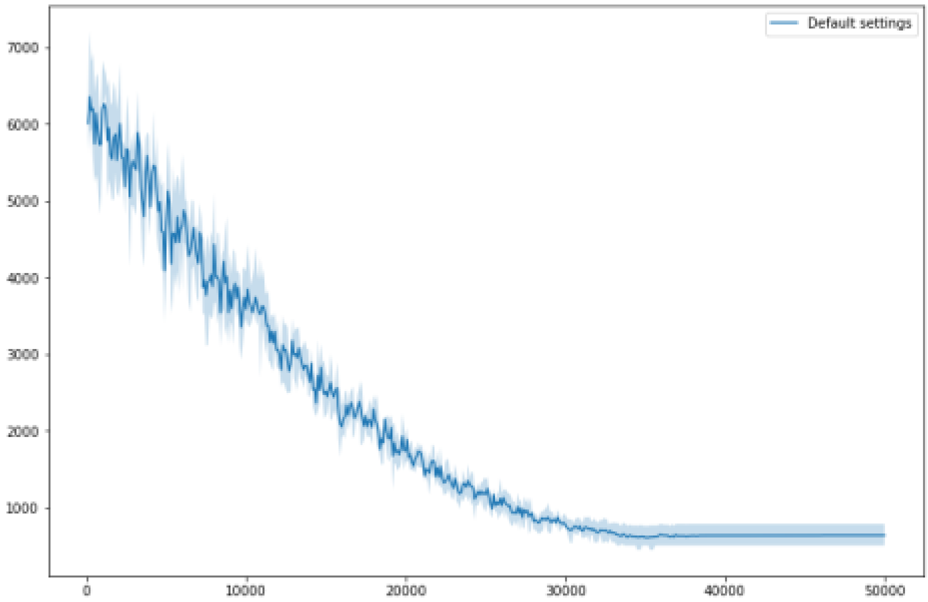
```
Run 0: difference = 636, bin weights = [27612, 27280, 27414, 27674, 27542, 27885, 27249, 27345, 27842, 27607]
Run 1: difference = 425, bin weights = [27312, 27552, 27637, 27737, 27661, 27676, 27555, 27381, 27550, 27389]
Run 2: difference = 707, bin weights = [27966, 27414, 27397, 27366, 27579, 27298, 27529, 27325, 27571, 28005]
Run 3: difference = 997, bin weights = [28087, 27257, 28007, 27753, 27098, 27094, 27090, 27913, 27794, 27357]
Run 4: difference = 418, bin weights = [27431, 27361, 27640, 27611, 27585, 27465, 27423, 27779, 27768, 27387]
Run 5: difference = 629, bin weights = [27451, 27648, 27899, 27899, 27579, 27406, 27270, 27419, 27405, 27474]
Run 6: difference = 797, bin weights = [27498, 27452, 27882, 27746, 27819, 27555, 27531, 27085, 27723, 27159]
Run 7: difference = 856, bin weights = [27857, 27851, 27628, 27583, 27537, 27531, 27372, 27307, 27783, 27001]
Run 8: difference = 662, bin weights = [27518, 27303, 27916, 27676, 27900, 27256, 27592, 27376, 27254, 27659]
Run 9: difference = 739, bin weights = [27474, 27573, 27193, 27106, 27820, 27627, 27687, 27845, 27688, 27437]
```



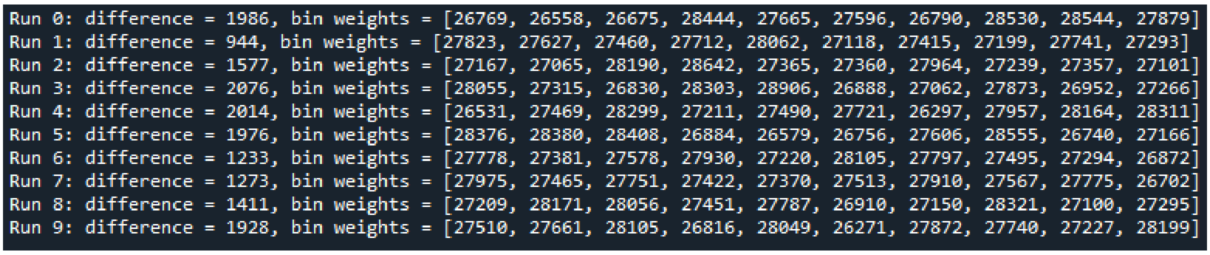
After multiple runs, the least difference value obtained with uniform crossover was 298 with Crossover probability at 80% & Mutation probability at 20%.



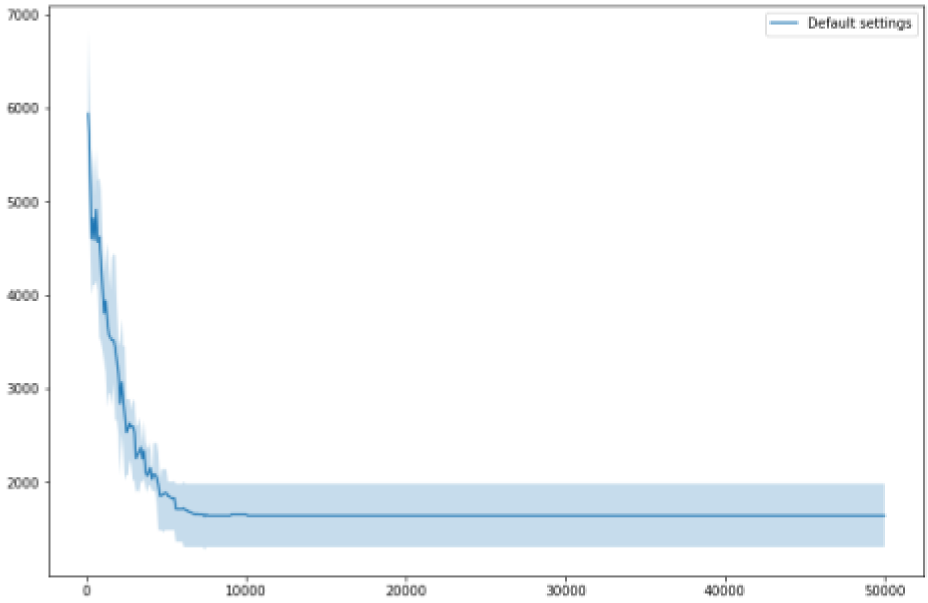
```
Run 0: difference = 630, bin weights = [27926, 27367, 27692, 27334, 27540, 27296, 27425, 27360, 27840, 27670]
Run 1: difference = 898, bin weights = [27671, 27819, 27247, 27645, 27484, 27759, 27137, 27038, 27936, 27714]
Run 2: difference = 735, bin weights = [27486, 27941, 27206, 27871, 27649, 27837, 27276, 27516, 27383, 27285]
Run 3: difference = 516, bin weights = [27635, 27731, 27659, 27215, 27621, 27565, 27506, 27667, 27312, 27539]
Run 4: difference = 794, bin weights = [27342, 27977, 27183, 27339, 27709, 27771, 27744, 27330, 27856, 27199]
Run 5: difference = 507, bin weights = [27476, 27749, 27697, 27595, 27734, 27362, 27332, 27242, 27614, 27649]
Run 6: difference = 429, bin weights = [27687, 27335, 27440, 27461, 27598, 27596, 27409, 27475, 27685, 27764]
Run 7: difference = 298, bin weights = [27673, 27483, 27574, 27477, 27543, 27681, 27537, 27541, 27558, 27383]
Run 8: difference = 774, bin weights = [27788, 27071, 27797, 27510, 27845, 27631, 27633, 27601, 27236, 27338]
Run 9: difference = 834, bin weights = [27773, 27097, 27777, 27931, 27396, 27544, 27924, 27115, 27483, 27410]
```

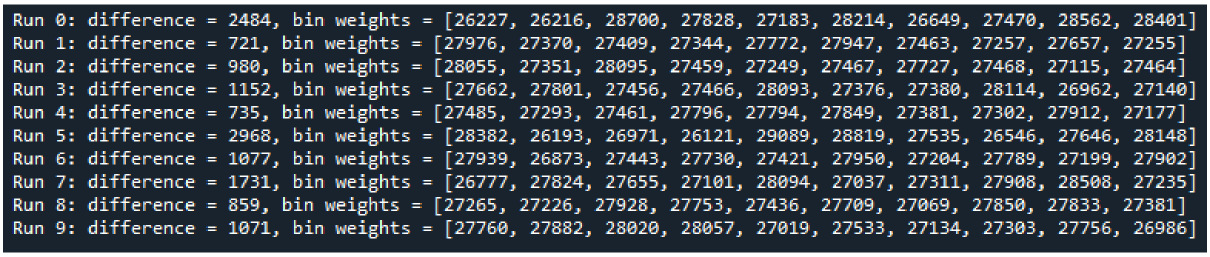


With Uniform_crossover & mutation prob at 20%.

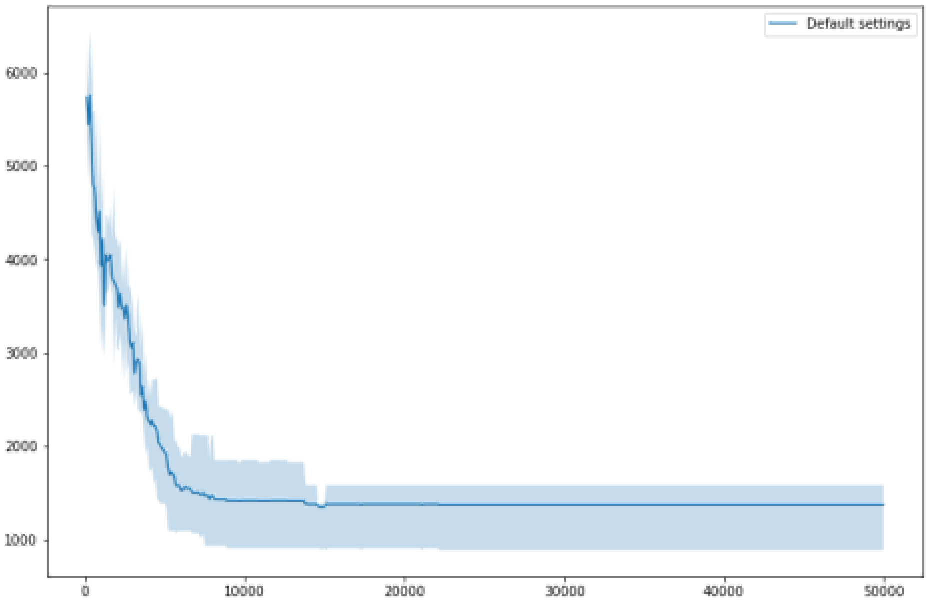


```
Run 0: difference = 1986, bin weights = [26769, 26558, 26675, 28444, 27665, 27596, 26790, 28530, 28544, 27879]
Run 1: difference = 944, bin weights = [27823, 27627, 27460, 27712, 28062, 27118, 27415, 27199, 27741, 27293]
Run 2: difference = 1577, bin weights = [27167, 27065, 28190, 28642, 27365, 27360, 27964, 27239, 27357, 27101]
Run 3: difference = 2076, bin weights = [28055, 27315, 26830, 28303, 28906, 26888, 27062, 27873, 26952, 27266]
Run 4: difference = 2014, bin weights = [26531, 27469, 28299, 27211, 27490, 27721, 26297, 27957, 28164, 28311]
Run 5: difference = 1976, bin weights = [28376, 28380, 28408, 26884, 26579, 26756, 27606, 28555, 26740, 27166]
Run 6: difference = 1233, bin weights = [27778, 27381, 27578, 27930, 27220, 28105, 27797, 27495, 27294, 26872]
Run 7: difference = 1273, bin weights = [27975, 27465, 27751, 27422, 27370, 27513, 27910, 27567, 27775, 26702]
Run 8: difference = 1411, bin weights = [27209, 28171, 28056, 27451, 27787, 26910, 27150, 28321, 27100, 27295]
Run 9: difference = 1928, bin weights = [27510, 27661, 28105, 26816, 28049, 26271, 27872, 27740, 27227, 28199]
```

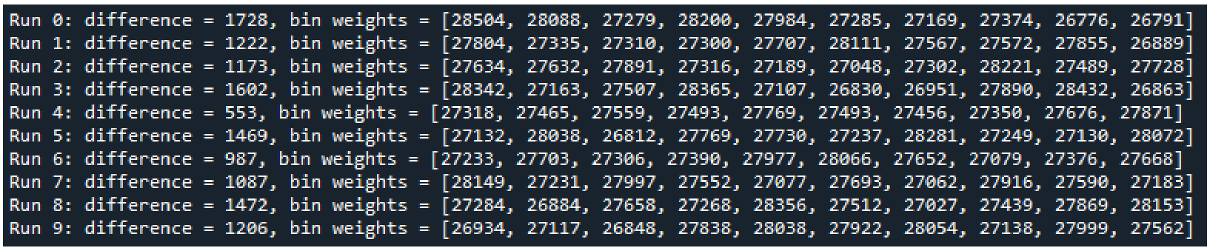




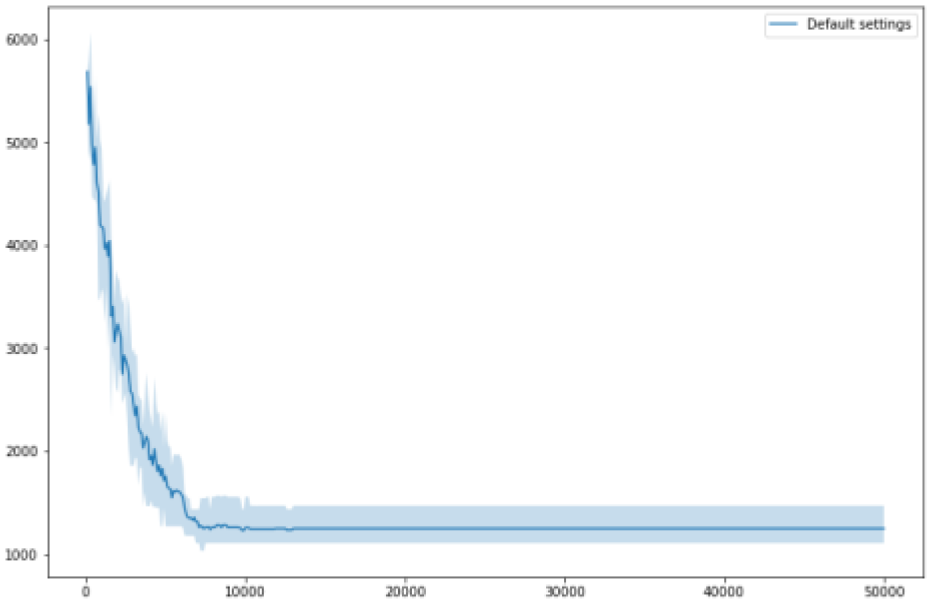
```
Run 0: difference = 2484, bin weights = [26227, 26216, 28700, 27828, 27183, 28214, 26649, 27470, 28562, 28401]
Run 1: difference = 721, bin weights = [27976, 27370, 27409, 27344, 27772, 27947, 27463, 27257, 27657, 27255]
Run 2: difference = 980, bin weights = [28055, 27351, 28095, 27459, 27249, 27467, 27727, 27468, 27115, 27464]
Run 3: difference = 1152, bin weights = [27662, 27801, 27456, 27466, 28093, 27376, 27380, 28114, 26962, 27140]
Run 4: difference = 735, bin weights = [27485, 27293, 27461, 27796, 27794, 27849, 27381, 27302, 27912, 27177]
Run 5: difference = 2968, bin weights = [28382, 26193, 26971, 26121, 29089, 28819, 27535, 26546, 27646, 28148]
Run 6: difference = 1077, bin weights = [27939, 26873, 27443, 27730, 27421, 27950, 27204, 27789, 27199, 27902]
Run 7: difference = 1731, bin weights = [26777, 27824, 27655, 27101, 28094, 27037, 27311, 27908, 28508, 27235]
Run 8: difference = 859, bin weights = [27265, 27226, 27928, 27753, 27436, 27709, 27069, 27850, 27833, 27381]
Run 9: difference = 1071, bin weights = [27760, 27882, 28020, 28057, 27019, 27533, 27134, 27303, 27756, 26986]
```



After multiple runs, the least difference value obtained with uniform crossover was 553 with Crossover probability at 95% & Mutation probability at 50%.

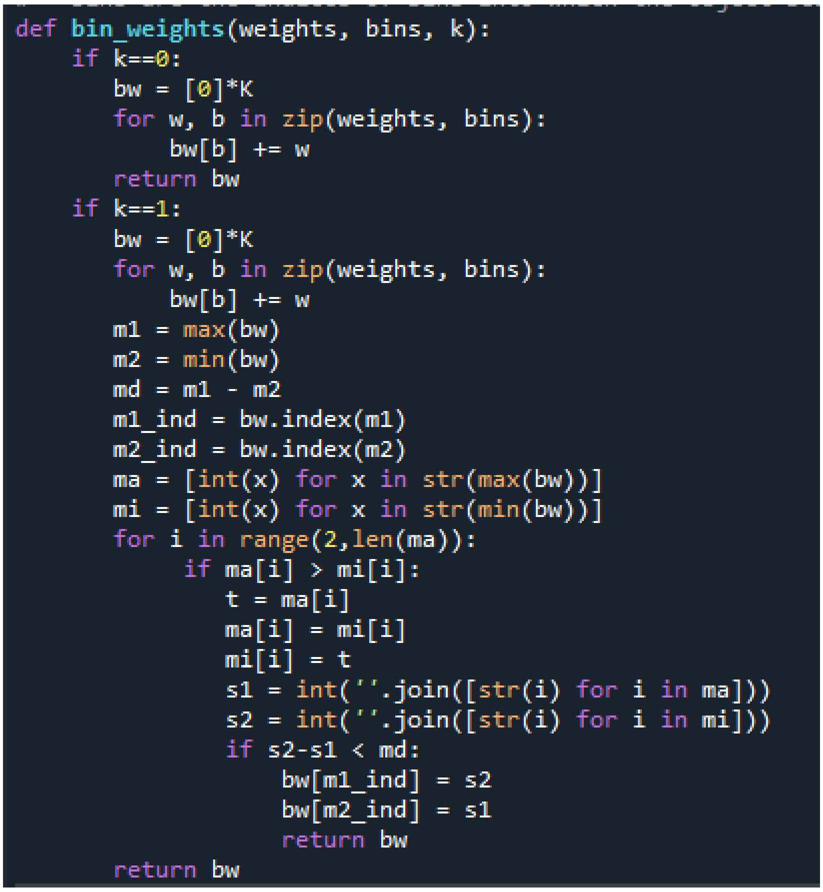


```
Run 0: difference = 1728, bin weights = [28504, 28088, 27279, 28200, 27984, 27285, 27169, 27374, 26776, 26791]
Run 1: difference = 1222, bin weights = [27804, 27335, 27310, 27300, 27707, 28111, 27567, 27572, 27855, 26889]
Run 2: difference = 1173, bin weights = [27634, 27632, 27891, 27316, 27189, 27048, 27302, 28221, 27489, 27728]
Run 3: difference = 1602, bin weights = [28342, 27163, 27507, 28365, 27107, 26830, 26951, 27890, 28432, 26863]
Run 4: difference = 553, bin weights = [27318, 27465, 27559, 27493, 27769, 27493, 27456, 27350, 27676, 27871]
Run 5: difference = 1469, bin weights = [27132, 28038, 26812, 27769, 27730, 27237, 28281, 27249, 27130, 28072]
Run 6: difference = 987, bin weights = [27233, 27703, 27306, 27390, 27977, 28066, 27652, 27079, 27376, 27668]
Run 7: difference = 1087, bin weights = [28149, 27231, 27997, 27552, 27077, 27693, 27062, 27916, 27590, 27183]
Run 8: difference = 1472, bin weights = [27284, 26884, 27658, 27268, 28356, 27512, 27027, 27439, 27869, 28153]
Run 9: difference = 1206, bin weights = [26934, 27117, 26848, 27838, 28038, 27922, 28054, 27138, 27999, 27562]
```



d) Modifying bin weights by swapping an individual between them.

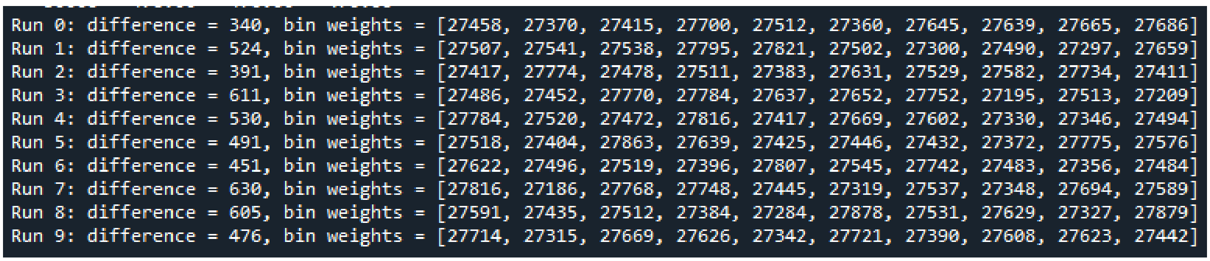
Code 1:



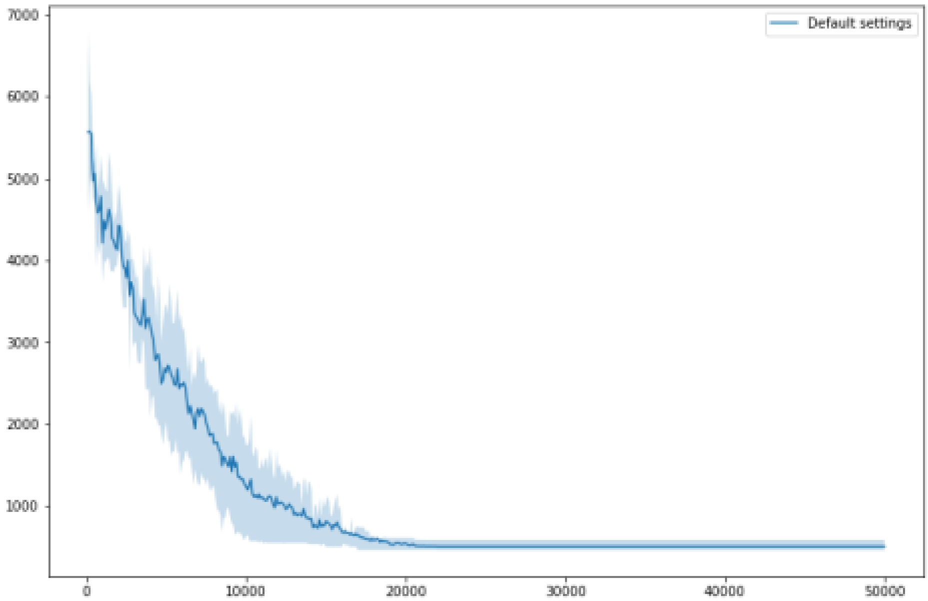
```
def bin_weights(weights, bins, k):
    if k==0:
        bw = [0]*K
        for w, b in zip(weights, bins):
            bw[b] += w
        return bw
    if k==1:
        bw = [0]*K
        for w, b in zip(weights, bins):
            bw[b] += w
        m1 = max(bw)
        m2 = min(bw)
        md = m1 - m2
        m1_ind = bw.index(m1)
        m2_ind = bw.index(m2)
        ma = [int(x) for x in str(max(bw))]
        mi = [int(x) for x in str(min(bw))]
        for i in range(2,len(ma)):
             if ma[i] > mi[i]:
                t = ma[i]
                ma[i] = mi[i]
                mi[i] = t
                s1 = int(''.join([str(i) for i in ma]))
                s2 = int(''.join([str(i) for i in mi]))
                if s2-s1 < md:
                    bw[m1_ind] = s2
                    bw[m2_ind] = s1
                    return bw
        return bw
```

Fig: The code modified for bin weights.

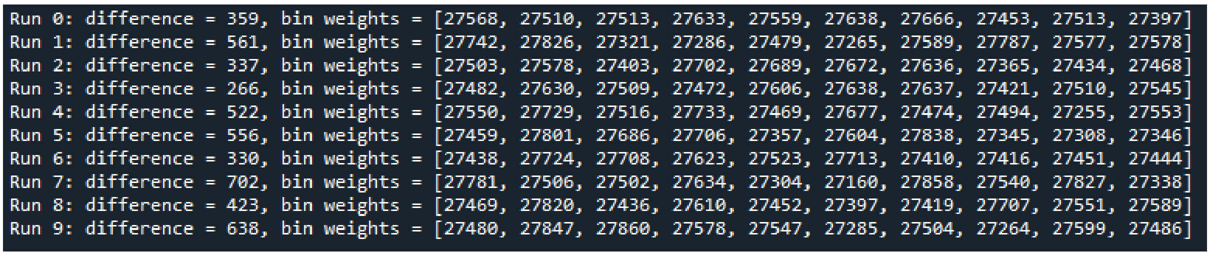
With Uniform Crossover probability -> 80% & Mutation(modified code from (c)) probability -> 20%.



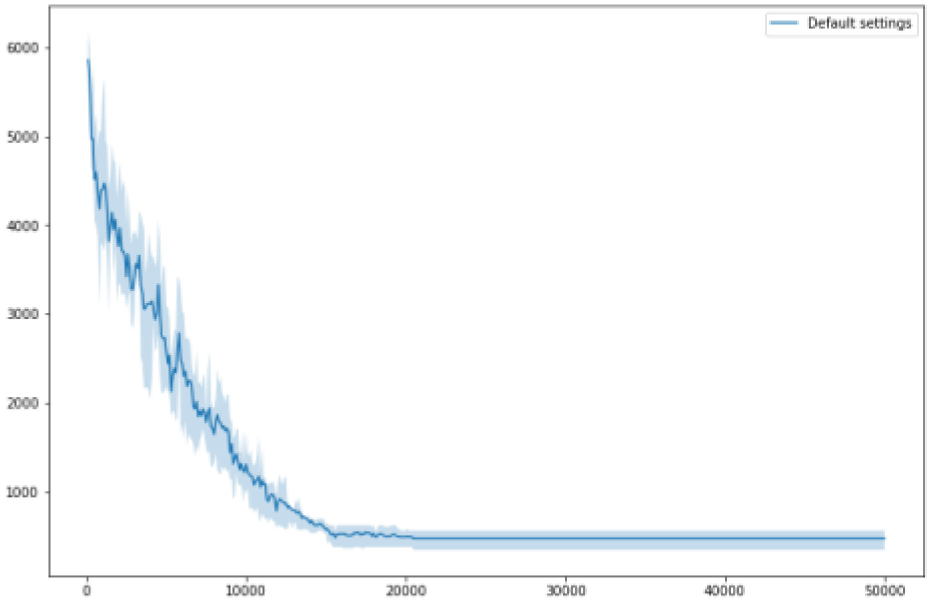
```
Run 0: difference = 340, bin weights = [27458, 27370, 27415, 27700, 27512, 27360, 27645, 27639, 27665, 27686]
Run 1: difference = 524, bin weights = [27507, 27541, 27538, 27795, 27821, 27502, 27300, 27490, 27297, 27659]
Run 2: difference = 391, bin weights = [27417, 27774, 27478, 27511, 27383, 27631, 27529, 27582, 27734, 27411]
Run 3: difference = 611, bin weights = [27486, 27452, 27770, 27784, 27637, 27652, 27752, 27195, 27513, 27209]
Run 4: difference = 530, bin weights = [27784, 27520, 27472, 27816, 27417, 27669, 27602, 27330, 27346, 27494]
Run 5: difference = 491, bin weights = [27518, 27404, 27863, 27639, 27425, 27446, 27432, 27372, 27775, 27576]
Run 6: difference = 451, bin weights = [27622, 27496, 27519, 27396, 27807, 27545, 27742, 27483, 27356, 27484]
Run 7: difference = 630, bin weights = [27816, 27186, 27768, 27748, 27445, 27319, 27537, 27348, 27694, 27589]
Run 8: difference = 605, bin weights = [27591, 27435, 27512, 27384, 27284, 27878, 27531, 27629, 27327, 27879]
Run 9: difference = 476, bin weights = [27714, 27315, 27669, 27626, 27342, 27721, 27390, 27608, 27623, 27442]
```



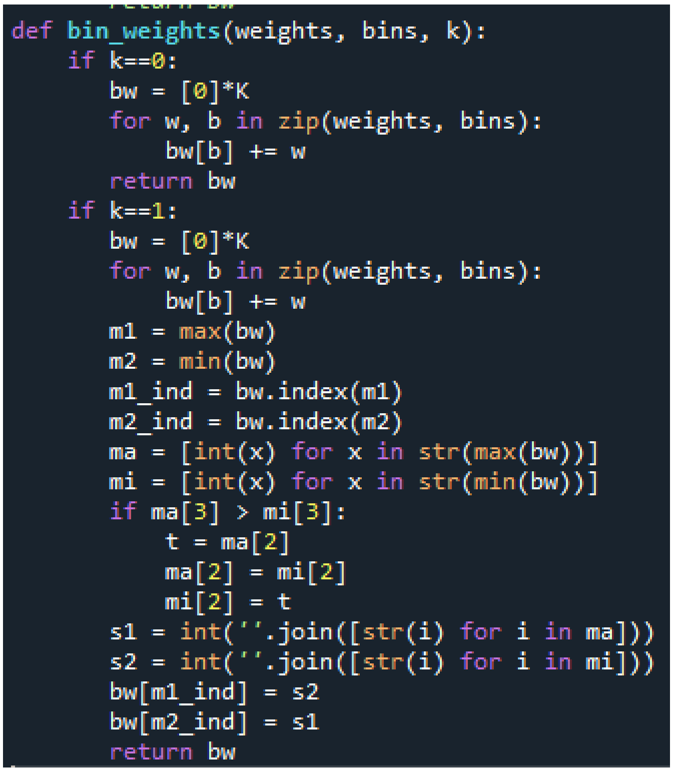
After multiple runs, the least difference value obtained was 266.



```
Run 0: difference = 359, bin weights = [27568, 27510, 27513, 27633, 27559, 27638, 27666, 27453, 27513, 27397]
Run 1: difference = 561, bin weights = [27742, 27826, 27321, 27286, 27479, 27265, 27589, 27787, 27577, 27578]
Run 2: difference = 337, bin weights = [27503, 27578, 27403, 27702, 27689, 27672, 27636, 27365, 27434, 27468]
Run 3: difference = 266, bin weights = [27482, 27630, 27509, 27472, 27606, 27638, 27637, 27421, 27510, 27545]
Run 4: difference = 522, bin weights = [27550, 27729, 27516, 27733, 27469, 27677, 27474, 27494, 27255, 27553]
Run 5: difference = 556, bin weights = [27459, 27801, 27686, 27706, 27357, 27604, 27838, 27345, 27308, 27346]
Run 6: difference = 330, bin weights = [27438, 27724, 27708, 27623, 27523, 27713, 27410, 27416, 27451, 27444]
Run 7: difference = 702, bin weights = [27781, 27506, 27502, 27634, 27304, 27160, 27858, 27540, 27827, 27338]
Run 8: difference = 423, bin weights = [27469, 27820, 27436, 27610, 27452, 27397, 27419, 27707, 27551, 27589]
Run 9: difference = 638, bin weights = [27480, 27847, 27860, 27578, 27547, 27285, 27504, 27264, 27599, 27486]
```



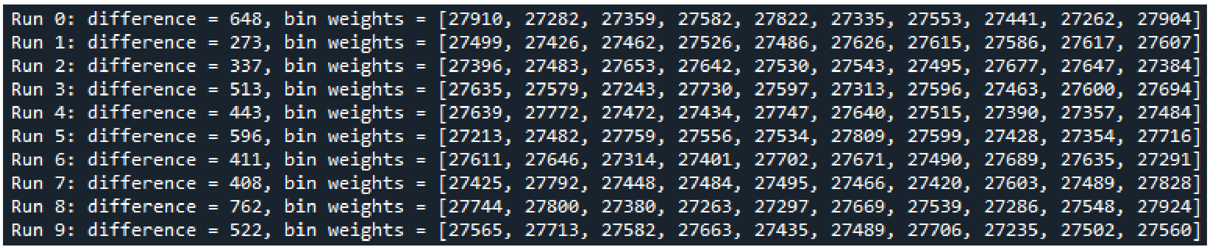
Code 2:



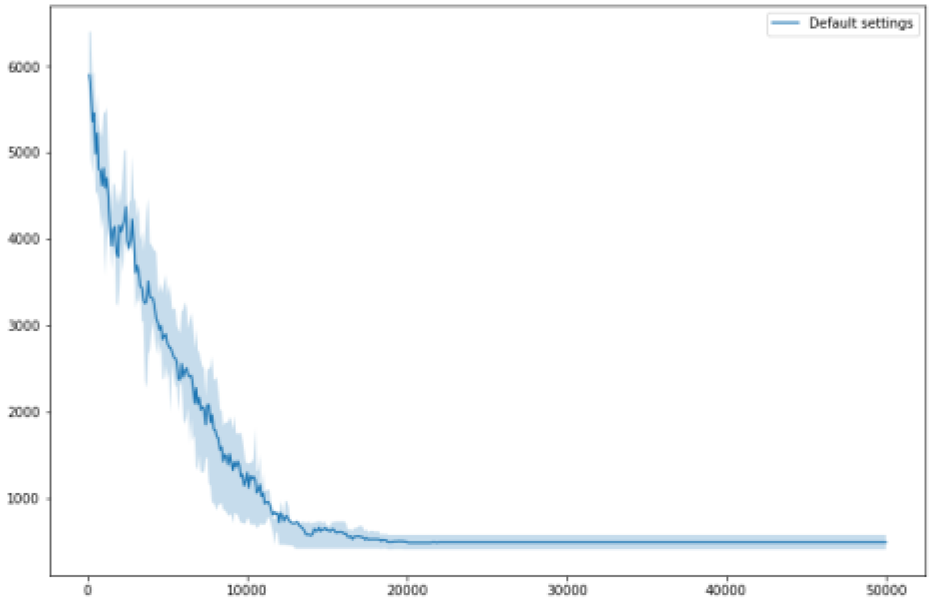
```
def bin_weights(weights, bins, k):
    if k==0:
        bw = [0]*K
        for w, b in zip(weights, bins):
            bw[b] += w
        return bw
    if k==1:
        bw = [0]*K
        for w, b in zip(weights, bins):
            bw[b] += w
        m1 = max(bw)
        m2 = min(bw)
        m1_ind = bw.index(m1)
        m2_ind = bw.index(m2)
        ma = [int(x) for x in str(max(bw))]
        mi = [int(x) for x in str(min(bw))]
        if ma[3] > mi[3]:
            t = ma[2]
            ma[2] = mi[2]
            mi[2] = t
        s1 = int(''.join([str(i) for i in ma]))
        s2 = int(''.join([str(i) for i in mi]))
        bw[m1_ind] = s2
        bw[m2_ind] = s1
        return bw
```

Fig: The code modified for bin weights(makes direct changes).

With Uniform Crossover probability -> 80% & Mutation(modified code from (c)) probability -> 20%.



```
Run 0: difference = 648, bin weights = [27910, 27282, 27359, 27582, 27822, 27335, 27553, 27441, 27262, 27904]
Run 1: difference = 273, bin weights = [27499, 27426, 27462, 27526, 27486, 27626, 27615, 27586, 27617, 27607]
Run 2: difference = 337, bin weights = [27396, 27483, 27653, 27642, 27530, 27543, 27495, 27677, 27647, 27384]
Run 3: difference = 513, bin weights = [27635, 27579, 27243, 27730, 27597, 27313, 27596, 27463, 27600, 27694]
Run 4: difference = 443, bin weights = [27639, 27772, 27472, 27434, 27747, 27640, 27515, 27390, 27357, 27484]
Run 5: difference = 596, bin weights = [27213, 27482, 27759, 27556, 27534, 27809, 27599, 27428, 27354, 27716]
Run 6: difference = 411, bin weights = [27611, 27646, 27314, 27401, 27702, 27671, 27490, 27689, 27635, 27291]
Run 7: difference = 408, bin weights = [27425, 27792, 27448, 27484, 27495, 27466, 27420, 27603, 27489, 27828]
Run 8: difference = 762, bin weights = [27744, 27800, 27380, 27263, 27297, 27669, 27539, 27286, 27548, 27924]
Run 9: difference = 522, bin weights = [27565, 27713, 27582, 27663, 27435, 27489, 27706, 27235, 27502, 27560]
```



Tried to optimize, but couldn’t get the least difference less than 100.