Correlation analysis between Filling Rate and Box Type in Container Loading Problem

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Abstract: This paper aims to study the correlation between filling rate and box type for guiding loading workers to grasp the best loading time. By collecting and analyzing the data in literature, we could find that the mean filling rates of weakly heterogeneous cases are much bigger than strongly heterogeneous instances, and weak heterogeneous loading problems could get far higher volume utilization than strong heterogeneous loading problems do. It is also found that 5-15 types is the best filling rate field in the best loading time.

1. Introduction

As a fundamental issue in the modern logistics, the “size coordination” problem has been widely researched in the past decades. Its main objective is to make a fixed space to be used effectively. One of the derived problems in the logistic is Container Loading Problem (CLP). This problem has been widely existing in many fields like railway, car, ship and container et al. Due to the capacity limitation of the transportation equipment, it is of great importance to maximize its loading volume to improve its utilization rate and economic efficiency in the logistic activities.

Nowadays, the researches mainly focus on the algorithm development to obtain high utilization of the container capacity. However, the proposed algorithm may not be effective to achieve the objective due to the complexity of container packing in practice. In the practical operation, container packing could be divided into two stages. The first stage is for goods accumulation, like compiling a list of goods to be installed (including size, weight, volume, special instructions) when the volume reaches a certain quantity. The second stage is to load the goods into the container. If there is a gap in the container, it will be filled with some isolated materials or fixed with wire. In order to pursue a higher utilization rate of container, freight departments do not begin to load until the total volume of cargoes for loading are several times larger than the volume of the container. When the loading starts, some of them are first selected to load, and the rest must wait for next round.

In the process of cargo loading, one question should be considered: what exactly is characteristics of cargoes to be loaded that affect container’s utilization rate? Apart from the total volume, it is worth investigating whether the type number of goods for loading impacts the filling rate. The research might provide a guide for the time of loading. Therefore, this paper proposes to study the correlation between filling rate and cargo type in container loading problem based on the published data in literature. The paper is organized as follows. In Section 2, we make the problem statement of this study. Section 3 explains the cases and algorithms employed for analysis in this paper, based on which in Section 4 we analyzes the computational results in literature. Finally we come to a conclusion in Section 5 and illustrate the future works.
2. Problem statement
The CLP is a three-dimensional packing problem in which a large parallelepiped or container has to be filled with smaller parallelepipeds or boxes. In other words, a given container is loaded with a subset of a given set of boxes in such a way that all boxes are positioned in a feasible way. The goal is to maximize the total volume of loaded boxes with the constraints. The two of the most common constraints are:

1. Constraint 1 (C1)
   Orientation constraint: For each box, the number of allowed orientation is restricted. For example, some boxes require that one side be always on top, such as the top side of a refrigerator must be always on top.

2. Constraint 2 (C2)
   Support constraint: To guarantee load stability, in a given packing plan the area of each box not placed on the floor of the container must be supported completely by other boxes.

Following the review paper by Bortfeld and Wascher(2013)[1], besides considering C1 and C2, Liu et al.(2017) [2] also takes the following three constraints into account:

1. Constraint 3 (C3)
   Guillotine cutting constraint: The length of a seam (“guillotine cut”) running through the stack must not exceed a certain maximum percentage of the stack’s maximum length or width.

2. Constraint 4 (C4)
   Complete-shipment constraint: If one item of a subset is loaded, all other items of that subset must also be loaded. Meanwhile, if one item cannot be loaded, no item of the subset will be loaded at all. For instance, many items that belong to a customer are required to be transported to a single place at the same time.

3. Constraint 5 (C5)
   Loading priority constraint: Since the available container space is not sufficient to accommodate all small items, it has to be decided which items have to be loaded first or be left behind.

It is observed in literature that the most of algorithms consider the C1 constraint in the study. Some of them further consider the C2 constraint. As far as we are concerned, only Liu et al.(2017)[2] takes all the C1-C5 as constraints.

The purpose of this paper is to reveal the correlation between filling rate and cargo type by analyzing the results coming from different algorithms, which consider different constraints.

3. Cases and algorithms used for analysis

| Approach | Source of Approach | Type of Method       |
|----------|--------------------|----------------------|
| B_HA     | Bischoff et al. (1995)[5] | Heuristic Approach(HA) |
| BR_HA    | Bischoff and Ratcliff(1995)[3] | HA |
| GB_GA    | Gehring and Bortfeldt(1997)[6] | Genetic Algorithm(GA) |
| BG_TS    | Bortfeldt and Gehring(1998)[7] | Tabu Search |
| BG_GA    | Bortfeldt and Gehring(2001)[8] | GA |
| BG_PGA   | Bortfeldt and Gehring(2002)[9] | Parallel GA |
| MO_GR    | Moura and Oliveira(2005)[10] | GRASP |
| P_MSA(5000) | Parreño et al.(2007)[11] | Maximal-Space Algorithm(MSA) |
| P_MSA(200000) | Parreño et al.(2007)[11] | MSA |
| Z_HSA    | Zhang et al.(2009)[12] | Hybrid Simulated Annealing |
| FB_TRS   | Fanslau and Bortfeldt(2010)[13] | Tree Search(TRS) |
In this paper, we choose 16 classical experiment cases BR0-BR15 that are commonly employed in literature. BR1-BR7 are generated by Bischoff and Ratcliff [3], while BR0 and BR8-BR15 are generated by Davies and Bischoff [4]. Each set includes 100 instances. There are 1600 instances in total. The number of types in 16 sets ranges from 1 to 100. BR0 only contains one kind of box, which means purely homogeneous loading instances. BR1-BR7 consist of a few types of boxes per instance and belong to weak heterogeneous loading problems. While BR8-BR15 are strongly heterogeneous loading problems that consist of up to 100 types of boxes per instance. All sets impose a variety of restrictions on the possible orientations for individual boxes. These instances can be downloaded from OR-Library or http://59.77.16.8/Download.aspx#p4.

There are many algorithms being proposed to solve container loading problem. We extracted all the results in these 16 sets by different approaches from the papers collected. These approaches are listed in Table 1. Each of them is named after authors and method’s acronym.

| Method       | Authors                          | Algorithm Description                                |
|--------------|----------------------------------|-----------------------------------------------------|
| HH_BS        | He and Huang(2010)[14]           | Beam Search(BS)                                     |
| P_VNS        | Parreño et al.(2010)[15]         | Variable Neighborhood Search                        |
| GR_PMGA      | Gonçalves and Resende (2011)[16]| Parallel Multi-population GA                         |
| HH_FDA       | He and Huang(2011)[17]           | Fit Degree Approach                                  |
| JM_PMRGA     | José and Mauricio(2012)[18]      | Parallel Multi-population biased Random-key GA       |
| ZL_GLTRS     | Zhu and Lim(2012)[19]            | Iterative-doubling Greedy-Lookahead TRS             |
| ZLW_SEBA     | Zhu, Lim and Weng(2012)[20]      | Six Elements to Block-building Approaches           |
| Z_HBMLS(S)   | Zhang et al. (2012)[21]          | Heuristic Block-loading Algorithm based on Multi-layer Search(HBMLS) |
| Z_HBMLS(C)   | Zhang et al. (2012)[21]          | HBMLS                                               |
| Z_HBMLS(SC)  | Zhang et al. (2012)[21]          | HBMLS                                               |
| Z_HBMLS(S_C2)| Zhang et al. (2012)[21]          | HBMLS                                               |
| Z_HBMLS(C_C2)| Zhang et al. (2012)[21]          | HBMLS                                               |
| Z_HBMLS(SC_C2)| Zhang et al. (2012)[21]         | HBMLS                                               |
| AR_BS        | Araya and Riff(2014)[22]         | BS                                                  |
| LTRS         | Liu et al.(2017)[2]              | TRS                                                 |
| L-HA         | Liu et al.(2017)[2]              | HA                                                  |

4. Data analysis
Tables 2-4 are filling rates (%) of the approaches in Table 1. All the data denote the average values for the 100 instances of each test case. Figure1-3 show the linear relationships between box type and filling rate of each approach.

| Class type | Filling rate(%) |
|------------|-----------------|
| B_HA       |                 |
| BR_HA      |                 |
| GB_GA      |                 |
| BG_TS      |                 |
| BG_GA      |                 |
| BG_PGA     |                 |
| MO_GR      |                 |
| P_MSA      |                 |

Table 2  Filling Rate of B_HA to PSA(5000)
| Class | BR1 | BR2 | BR3 | BR4 | BR5 | BR6 | BR7 | BR8 | BR9 | BR10 | BR11 | BR12 | BR13 | BR14 | BR15 |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|
| 3     | 81.76 | 83.37 | 86.77 | 92.63 | 87.81 | 88.1 | 89.07 | 93.27 |
| 5     | 81.7  | 83.57 | 88.12 | 92.7  | 89.4  | 89.56 | 90.43 | 93.38 |
| 8     | 82.98 | 83.59 | 88.87 | 92.31 | 90.48 | 90.77 | 90.9  | 93.39 |
| 10    | 82.6  | 84.16 | 88.68 | 91.62 | 90.63 | 91.03 | 90.42 | 93.16 |
| 12    | 82.76 | 83.89 | 88.78 | 90.86 | 90.73 | 91.23 | 89.57 | 92.89 |
| 15    | 81.5  | 82.92 | 88.53 | 90.04 | 90.72 | 91.28 | 89.71 | 92.62 |
| 20    | 80.51 | 82.14 | 88.36 | 88.63 | 90.65 | 91.04 | 88.05 | 91.86 |
| 30    | 79.65 | 80.1  | 87.52 | 87.11 | 89.73 | 90.26 | 86.13 | 91.02 |
| 40    | 80.19 | 78.03 | 86.46 | 85.76 | 89.06 | 89.5  | 85.08 | 90.46 |
| 50    | 79.74 | 76.53 | 85.53 | 84.73 | 88.4  | 88.73 | 84.21 | 89.87 |
| 60    | 79.23 | 75.08 | 84.82 | 83.55 | 87.53 | 87.87 | 83.98 | 89.36 |
| 70    | 79.16 | 74.37 | 84.25 | 82.79 | 86.94 | 87.18 | 83.64 | 89.03 |
| 80    | 78.23 | 73.56 | 83.67 | 82.29 | 86.25 | 86.7  | 83.54 | 88.56 |
| 90    | 77.4  | 73.37 | 82.99 | 81.33 | 85.55 | 85.81 | 83.25 | 88.46 |
| 100   | 75.15 | 73.38 | 82.47 | 80.85 | 85.23 | 85.48 | 83.21 | 88.36 |
| Mean 1-7(W) | 81.97 | 83.38 | 88.30 | 91.26 | 90.06 | 90.43 | 89.73 | 92.94 |
| Mean 8-15(S) | 78.59 | 75.55 | 84.71 | 83.55 | 87.34 | 87.69 | 84.13 | 89.39 |

W-S 3.38 7.82 3.59 7.70 2.72 2.74 5.60 3.55
Box type of best value 8 10 8 5 12 15 8 8

Note: The best values appear in bold

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![Figure 1](image-url)  
**Figure 1 Curve Graphs from Method B_HA to Method PSA(5000)**

| Class | Box type | Filling rate (%) |
|-------|----------|------------------|
| BR1   | 3        | 93.85 93.81 94.51 87.54 94.9 95.28 92.92 94.34 |
| BR2   | 5        | 94.22 93.94 94.73 89.12 95 95.9 93.93 94.88 |

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**Table 3 Filling Rate of PSA(20000) to JM_PMRGA**

| Class | Box type | Filling rate (%) |
|-------|----------|------------------|
| BR1   | 3        | 93.85 93.81 94.51 87.54 94.9 95.28 92.92 94.34 |
| BR2   | 5        | 94.22 93.94 94.73 89.12 95 95.9 93.93 94.88 |
BR3  8  94.25  93.86  94.74  90.32  95  96.1  93.71  95.05  
BR4  10  94.09  93.57  94.41  90.57  94.7  96.01  93.68  94.75  
BR5  12  93.87  93.22  94.13  90.78  94.3  95.84  93.73  94.58  
BR6  15  93.52  92.72  93.85  90.91  94  95.72  93.63  94.39  
BR7  20  92.94  91.99  93.2  90.88  93.5  95.29  93.14  93.74  
BR8  30  91.02  90.56  92.26  90.85  92.8  94.76  92.92  92.65  
BR9  40  90.46  89.7  91.48  90.64  92.2  94.34  92.49  91.9  
BR10  50  89.87  89.06  90.86  90.43  91.9  93.86  92.24  91.28  
BR11  60  89.36  88.18  90.11  90.23  91.5  93.6  91.91  90.39  
BR12  70  89.03  87.73  89.51  89.97  91.2  93.22  91.83  89.81  
BR13  80  88.56  86.97  88.98  89.88  91.1  92.99  91.56  89.27  
BR14  90  88.46  86.16  88.26  89.67  90.6  92.68  91.3  88.57  
BR15  100  88.36  85.44  87.57  89.54  90.4  92.46  91.02  87.96  
Mean 1-7(W)  93.82  93.30  94.22  90.02  94.53  95.74  93.53  94.53  
Mean 8-15(S)  89.39  87.98  89.88  90.15  91.46  93.49  91.91  90.23  
W-S  4.43  5.33  4.35  -0.13  3.07  2.25  1.63  4.30  

**Box type of best value**

8  5  8  15  5  8  5  8

*Note: The best values appear in bold*

From Table 2 and Table 3, one can see that the best value is distributed in a certain range of the box types between 5 and 15. This phenomenon can also be found in Figure 1 and Figure 2. Each curve reaches peak point when box type is less than 20 and then goes down gradually. Meanwhile, all approaches' mean filling rates of BR1-BR7 are far higher than BR8-BR15's, the biggest difference of W-S is 7.82, except for the approach HH_BS whose average filling rate of BR8-BR15 is slightly greater than BR1-BR7’s. However, it gets its best value when box type is 15, indicating that in most of cases the volume utilization of weak heterogeneous CLP will be higher than strong heterogeneous CLP's.

![Figure 2: Curve Graphs from Method PSA(20000) to Method JM_PMORGA](image-url)
### Table 4  Filling Rate of ZL_GLTS to AR_BSA

| Class | Box type | Filling rate(%) | ZL_GLTS (W) | ZLW_SE (W) | Z_HBML (S) | Z_HBML (SC) | Z_HBML (SC_C2) | Z_HBML (SC_C2) | AR_BSA |
|-------|----------|----------------|-------------|------------|------------|-------------|----------------|----------------|--------|
| BR0   | 1        | 90.79          | 90.8        | 89.9       | 89.77      | 89.95       | 89.76          | 89.69          | 89.81  |
| BR1   | 3        | 95.59          | 95.54       | 94.87      | 93.54      | 94.92       | 94.3           | 93.95          | 94.43  |
| BR2   | 5        | 96.13          | 95.98       | 95.41      | 94.47      | 95.48       | 94.74          | 94.39          | 94.87  |
| BR3   | 8        | 96.3           | 96.08       | 95.6       | 95.12      | 95.69       | 94.89          | 94.67          | 95.06  |
| BR4   | 10       | 96.15          | 95.94       | 95.38      | 95.1       | 95.53       | 94.69          | 94.54          | 94.89  |
| BR5   | 12       | 95.98          | 95.74       | 95.22      | 95.08      | 95.44       | 94.53          | 94.41          | 94.68  |
| BR6   | 15       | 95.81          | 95.61       | 95.1      | 95.21      | 95.38       | 94.32          | 94.25          | 94.53  |
| BR7   | 20       | 95.36          | 95.14       | 94.6       | 94.87      | 95          | 93.78          | 93.69          | 93.96  |
| BR8   | 30       | 94.8           | 94.63       | 94.16      | 94.6       | 94.66       | 92.88          | 93.13          | 93.27  |
| BR9   | 40       | 94.53          | 94.29       | 93.76      | 94.24      | 94.3        | 92.07          | 92.54          | 92.6   |
| BR10  | 50       | 94.35          | 94.05       | 93.38      | 94.08      | 94.11       | 91.28          | 92.02          | 92.05  |
| BR11  | 60       | 94.14          | 93.78       | 92.87      | 93.86      | 93.87       | 90.48          | 91.45          | 91.46  |
| BR12  | 70       | 94.1           | 93.67       | 92.59      | 93.67      | 93.67       | 89.65          | 90.91          | 90.91  |
| BR13  | 80       | 93.86          | 93.54       | 92.25      | 93.45      | 93.45       | 88.75          | 90.43          | 90.43  |
| BR14  | 90       | 93.83          | 93.36       | 91.84      | 93.34      | 93.34       | 87.81          | 89.8           | 89.8   |
| BR15  | 100      | 93.78          | 93.32       | 91.53      | 93.14      | 93.14       | 86.94          | 89.24          | 89.24  |

**Mean 1-7(W)**  
95.90           95.72           95.16           94.77           95.35           94.46           94.27           94.63           96.10  
**Mean 8-15(S)**  
94.17           93.83           92.80           93.80           93.82           89.98           91.19           91.22           94.78  
**W-S**  
1.73            1.89            2.37            0.97            1.53            4.48            3.08            3.41            1.32  

**Box type of best value**  
8             8             8             15            8             8             8             8            8  

**Note:** The best values appear in bold.
In Table 4, all the approaches have the value of set BR0 whose box type equals to 1. We can see from Table 4, the BR0’s filling rate is much lower than BR1’s, method $Z_{HBMLSS(C_2)}$’s is even smaller than its BR15’s. Each algorithm gets its best value when box type equals to 8 except method $Z_{HBMLSC(C)}$, which reaches its peak point when the box type is 15. Similarly, the BR1-BR7’s average filling rates largely outweigh the BR8-BR15’s. Figure3 also demonstrates these characteristics. For instance, a dramatic growth could be noticed from BR0 to BR1, next to mild and short increase, then smooth decline. Thus, assuming that the quantity is sufficient, if there is only one type or too many types boxes (more than 30) to be loaded, the container volume utilization is not good, only in the case of a intermediate number of box types (greater than 3 and less than 20) can the container be better utilized or even reach the best filling rate irrespective of algorithms adopted. In a word, it is easy to get the higher volume utilization in weakly heterogeneous situations instead of strongly heterogeneous instances.

Some authors report computational results where the support constraint(C2) is not enforced, but approaches that enforces the support constraint(C2) still show the same characteristics, such as, $Z_{HBMLSS(C_2)}$, $Z_{HBMLSC(C_2)}$, $Z_{HBMLSC(C_2)}$ in table 4. In order to observe the characteristics incorporating other three constraints C3-C5 mentioned in section 2, let’s take a look at the data (Table 5) cited from Liu et al.(2017)[2]. Approach L-TRS considers constraints C1, C2&C3. Algorithm L-HA takes constraints C1-C5 into account, and the items are grouped into orders which have different loading priorities. Specifically, we divide the sequence of orders in each case of BR1-BR15 into two subsets (named sub1 and sub2) according to 9 different ratios: 9:1, 8:2, . . . , 1:9. For each proportion, the orders in sub1 are expiring, while the orders in sub2 are non-expiring. All the data in Table 5 denotes the mean filling rate(%) for each case. As shown in Table 5, BR1-BR7 obtain better results than BR8-BR15, their mean differences are more than 3 except by method L-TRS which is 1. The number of box type obtaining best value ranges between 8, 10, and 12. As can be seen from Figure4, the curve of L-TRS goes up sharply and then goes down slowly, with only one place fluctuating slightly. All the curves of approach L-HA also show the same trend, but they are near and overlapped. In addition, the descent speed are gently greater and more places are fluctuated. However, all features are similar to those mentioned in the previous two paragraphs. As a result, no matter what constraints are consideration, weakly heterogeneous cases have better volume utilization than strongly heterogeneous instances, and the best filling rate always occurs not in the strongly heterogeneous situations, but in the weakly heterogeneous situations.
Now let us have a look at the mean of all the approaches and the number of cases which get the best value. Since some algorithms do not solve BR0, here we calculate the mean filling rates of BR1-BR15 (Table 6) for the purpose of comparison. The difference between W and S is 3.24, telling that weak heterogeneous loading problems can acquire greater filling rates than strong heterogeneous loading problems. In weakly heterogeneous cases, BR3 has the highest chance to get the best value, which is 65.71% according to Figure 6. Next are BR2, BR5 and BR6 respectively and BR4 is the last. In the approaches collected in this paper, the number of BR7 gets the best value as zero and strongly heterogeneous cases are not mentioned.

| Class | Box type | 9:1   | 8:2   | 7:3   | 6:4   | 5:5   | 4:6   | 3:7   | 2:8   | 1:9   |
|-------|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| BR1   | 3        | 90.62 | 87.96 | 87.44 | 87.48 | 87.19 | 87.3  | 87.72 | 87.8  | 87.75 | 87.64 |
| BR2   | 5        | 91.51 | 88.18 | 87.97 | 87.46 | 87.53 | 87.57 | 87.62 | 87.76 | 87.47 | 87.99 |
| BR3   | 8        | 92.43 | 88.75 | 88.16 | 88.33 | 88.22 | 88.34 | 88.19 | 88.25 | 88.44 | 88.52 |
| BR4   | 10       | 92.35 | 88.61 | 88.02 | 88.0  | 87.97 | 87.98 | 88.13 | 88.45 | 88.21 | 88.4  |
| BR5   | 12       | 92.45 | 88.57 | 88.18 | 88.11 | 87.92 | 88.17 | 87.89 | 88.35 | 88.27 | 88.03 |
| BR6   | 15       | 92.37 | 88.18 | 87.85 | 87.91 | 87.59 | 87.56 | 87.77 | 88.02 | 87.47 | 87.63 |
| BR7   | 20       | 92.13 | 88.04 | 87.5  | 87.15 | 87.48 | 87.61 | 87.22 | 87.44 | 87.37 | 87.11 |
| BR8   | 30       | 91.95 | 87.1  | 86.56 | 86.6  | 86.19 | 86.55 | 86.46 | 86.61 | 86.35 | 86.54 |
| BR9   | 40       | 91.64 | 86.44 | 86.08 | 85.68 | 85.8  | 86.0  | 85.93 | 85.54 | 86.02 | 85.9  |
| BR10  | 50       | 91.42 | 85.84 | 85.28 | 84.92 | 84.79 | 85.4  | 84.8  | 85.34 | 84.83 | 84.72 |
| BR11  | 60       | 91.14 | 85.37 | 84.83 | 84.95 | 84.76 | 84.85 | 84.47 | 84.21 | 84.75 | 84.43 |
| BR12  | 70       | 90.98 | 84.91 | 84.06 | 84.1  | 84.0  | 84.03 | 84.57 | 83.97 | 84.12 | 83.89 |
| BR13  | 80       | 90.60 | 84.28 | 83.88 | 83.61 | 83.88 | 83.63 | 83.98 | 83.77 | 84.14 | 83.75 |
| BR14  | 90       | 90.27 | 83.95 | 83.34 | 83.23 | 83.75 | 83.37 | 83.49 | 83.53 | 83.45 | 83.14 |
| BR15  | 100      | 89.84 | 83.9  | 83.21 | 83.09 | 82.97 | 83.25 | 82.94 | 83.43 | 83.41 | 83.29 |
| Mean 1-7(W) | 91.98 | 89.87 | 88.33 | 87.87 | 87.78 | 87.70 | 87.79 | 87.79 | 88.01 | 87.85 |
| Mean 8-15(S) | 90.98 | 87.63 | 85.22 | 84.66 | 84.52 | 84.52 | 84.64 | 84.48 | 84.55 | 84.63 |
| W-S   | 1.00     | 3.10  | 3.22  | 3.25  | 3.18  | 3.16  | 3.21  | 3.46  | 3.22  | 3.45  | 3.45 |

Note: The best values appear in bold
Figure 4  L-TRS’s and L-HA’s Curve Graph

Table 6  Mean Filling Rate of All Approaches

| Class | Box type | Mean  | No. of Best Value |
|-------|----------|-------|-------------------|
| BR1   | 3        | 90.91 | 0                 |
| BR2   | 5        | 91.42 | 4                 |
| BR3   | 8        | 91.82 | 23                |
| BR4   | 10       | 91.68 | 2                 |
| BR5   | 12       | 91.55 | 3                 |
| BR6   | 15       | 91.28 | 3                 |
| BR7   | 20       | 90.78 | 0                 |
| BR8   | 30       | 89.93 | 0                 |
| BR9   | 40       | 89.32 | 0                 |
| BR10  | 50       | 88.71 | 0                 |
| BR11  | 60       | 88.2  | 0                 |
| BR12  | 70       | 87.77 | 0                 |
| BR13  | 80       | 87.38 | 0                 |
| BR14  | 90       | 86.94 | 0                 |
| BR15  | 100      | 86.6  | 0                 |
| Mean 1-7(W) | 91.35 | 0 |
| Mean 8-15(S) | 88.11 | 0 |
| W-S   | 3.24     | 0     |

Note: The best values appear in bold
5. Conclusions and future works

All in all, from the analysis of section 4, whichever algorithms and constraints taken according to existing literature, the mean filling rates of weakly heterogeneous cases are far bigger than strongly heterogeneous instances. Box type ranging from 5 to 15 has the opportunity to obtain the best filling rate, and has the maximum possibility when it equals to 8. Besides, the filling rate under purely homogeneous loading instances is also not better than weakly heterogeneous cases. So in practical loading operation, loading workers need wait for cargoes with different size, but not too many types. 5-15 types are the best loading time, which is also the best value fields. While, the results were just gotten by statistically and not been mathematically deduced, which might have defects and deficiencies, and the future work may lie in further mathematical deduction of the foundation drawn in this work. In addition to volume utilization, this paper just discusses volume utilization, it is necessary to consider weight capacity utilization in the future research.

Acknowledgments
The authors would like to thank Dr. Yandong Huang from Jimei University for helpful comments. And the work was supported by the Science Foundation of Fujian, China(Grant nos. JA13179 and 2016J01763).

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