BACHELOR THESIS: THE CARGO FARE CLASS MIX PROBLEM – REVENUE MANAGEMENT IN SYNCHROMODAL CONTAINER TRANSPORTATION

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1 INTRODUCTION

With increasing demand for reliable and quick service, the need for efficient network planning is growing. Intermodal hinterland transportation of maritime containers also faces this problem, there is a need for development. In practice the operator of an inland transportation network has limited flexibility for integral optimisation: consignees often order for transportation with a fixed mode, route and time (Van Riessen *et al.*, 2015). This makes it difficult to develop efficient transportation plans. Introducing different fare classes with other requirements of service, creates some room to implement an optimisation and increase the revenue. This paper focuses on the revenue management of the intermodal hinterland transportation of maritime containers.

In this paper we study the model by Van Riessen *et al* (2015) which includes different fare classes. First we will reproduce their results. The model is based on a Cargo Fare Class Mix problem, with r routes, d destinations and p fare classes (CFCM(r,d,p)). In this paper a particular CFCM problem is investigated, the CFCM(1,1,2) problem, this is the model with one route, one destination and two fare classes. The classes are differentiated in price and time window of delivery. The different fare classes introduced for the model are the "Basic" class (B), where the delivery time is within two days, and the "Express" class (E), where the delivery time is within one day. The fare for the Express class is higher than for the Basic class.

The challenge in the CFCM(1,1,2) problem is to find optimal booking limits for the different fare classes in order to maximise the revenue. A framework for the size of the booking limits will be provided in differentiated service portfolios with heterogeneous planning characteristics. This paper is based on the paper of Van Riessen *et al* (2015).

For further research of the problem a parameter analysis will be provided in two different ways. The first parameter analysis is based on the one-factor-at-a-time (OFAT) approach, this means that one parameter will be changed while the other parameters are fixed at their nominal values. This is repeated for all the parameters. The booking limits are adjusted to the parameter change. The second parameter analysis is done where the booking limits are determined beforehand and the demand for the two different fare classes are changed.

1.1 RESEARCH QUESTION

What are the optimal booking limits using a CFCM(1,1,2) model in intermodal hinterland transportation, taken into account the maximization of the revenue?

2 LITERATURE REVIEW

2.1 INTERMODAL NETWORKS

Multimodal freight transportation is defined as the transportation of goods by a sequence of at least two different modes of transportation (Steadiseifi *et al.*, 2014). Intermodal transportation is a type of multimodal transportation where the cargo is transported in one and the same unit, for example a container. In SteadiSeafi *et al* (2014) an overview of intermodal planning papers from 2005 and onwards is given. Also the definitions for the different transportation methods i.e. multimodal, intermodal, co-modal and synchromodal, are studied in this paper. It is explained that multimodal and intermodal in literature is used interchangeable.

2.2 REVENUE MANAGEMENT

The revenue management with different fare classes for the cargo in intermodal hinterland transportation, is very similar to the revenue management of the fare class mix problem in the air transport industry. The amount of seats that should be available for every fare class in airline revenue management can be compared to the fare class booking limits in the intermodal hinterland transportation. Barnhart *et al* (2003) gives a good overview of the operations research in the aviation industry. In Belobaba (1989) a model for airline seat inventory control is described. The difference in the paper from the CFCM problem is that the booking limits become dynamic as the departure day approaches and the actual booking process is taken into account. Their approach is to find the amount of spots not to sell in the lower fare classes, so those spots can be sold to the higher fare classes. Therefore, the problem is to find the 'protection levels' for the higher fare classes and then determine the booking limits for the lower fare classes.

In the paper of Pak and Dekker (2014) the cargo revenue management of the air transport is investigated. In the paper a booking request is accepted if the revenue for accepting the shipment is higher or equal to the estimated opportunity costs of the capacities of the shipment. In the air transport cargo, the capacity includes a weight and a volume, whereas in this paper only a capacity of the volume is taken into account. In Bartodziej *et al* (2007) a model is introduced for revenue management to evaluate the profitability of a request at a certain price. Also a simulation study is done to evaluate the approach. Again this paper is based on the cargo in air transportation, taken into account the weight of the cargo.

The cargo fare class mix model of differentiated services with different planning statistics is not yet described in other literature then Van Riessen *et al* (2015). There are some similarities in the existing literature and the CFCM model, but in the CFCM model the operator must balance between two fare classes with different planning characteristics. Hence, this paper includes a new approach to the revenue management in the cargo industry.

3 THE CFCM(1,1,2) MODEL

3.1 MODELLING FRAMEWORK

In this section we will describe the CFCM(1,1,2) model: the model with one route, one destination and two fare classes. The distribution of the number of daily transportation request for Express and Basic are denoted as $N_E(t)$ and $N_B(t)$. $N_E(t)$ and $N_B(t)$ are assumed to be independent and not identical.

$$(t) \sim p(k) = P(N_E = k), k = 1,2,...,$$

$$N_{\mathrm{B}}(t) \sim p_{\mathrm{B}}(k) = P(N_{\mathrm{B}} = k), k = 1,2,...,$$

Where p(k) denotes the probability of receiving k transportation requests on a day.

The requests for transportation of a fare class is accepted until the booking limit is reached. The booking limits, denoted by L_E and L_B for Express and Basic cargo, have to be determined. A daily capacity C can be used for the transportation of the cargo. The booking limits should be set with taken into account the capacity C. This means that the booking limit L_E cannot exceed C ($L_E \leq C$) and therefore all accepted Express cargo can be shipped.

The shipping cargo consists of three types, the demand of Express shipping today D_E, the demand of Basic shipping today D_B, or the remaining demand of Basic shipping from the day before R_B. The transported goods can exist of three stages:

1. The capacity is sufficient to transport D_E and a part of R_B, a penalty is given for the part of R_B that is not transported and a remainder is present for the next day.
2. The capacity is sufficient to transport D_E , R_B and a part of D_B, no penalty is given, but there is still some remaining cargo that needs to be transported.
3. The capacity is sufficient to transport D_E, R_B and D_B, all demand is therefore transported.

The distributions of the daily accepted demand for Express and Basic cargo become:

$$\mathrm{D_E}(t) = \min(N_\mathrm{E}(t), \mathrm{L_E}), \mathrm{D_B}(t) = \min(N_\mathrm{B}(t), \mathrm{L_B}) \tag{1}$$

$$(D_\mathrm{E}(t) = k) = p_\mathrm{E}(k), k = 1,2,...,L_\mathrm{E} - 1 \tag{2}$$

$$(D_\mathrm{B}(t) = k) = p_\mathrm{B}(k), k = 1,2,...,L_\mathrm{B} - 1 \tag{3}$$

$$(D_\mathrm{E}(t) = L_\mathrm{E}) = 1 - \sum_{k=0}^{L_E-1} p_E(\mathrm{k})$$

$$(D_\mathrm{B}(t) = L_\mathrm{B}) = 1- \sum_{k=0}^{L_B-1} p_B(\mathrm{k})$$

With J the total revenue from the accepted demand, the objective function becomes:

$$\max_{L_E,L_B} J = f_\mathrm{E}(D_E) + f_\mathrm{B}(D_\mathrm{B}) - p\mathbb{E}(\mathrm{E_B}) \tag{4}$$

Where p denotes the penalty for all excess demand E_B.

3.2 Derivation of the model

In the paper of Van Riessen *et al* (2015), the derivation of the equations can be found, however for the integrity of this paper the derivation will be repeated.

To solve the objective function (4), first an equation for the expected value of D_E, D_B and E_B is derived:

$$(D_E) = \sum_{k=0}^{L_E} kP(D_E = k) = \sum_{k=1}^{L_E-1} kp_E(k) + L_E\left(1 - \sum_{k=0}^{L_E-1} p_E(k)\right) \tag{5}$$

$$(D_B) = \sum_{k=1}^{L_B-1} kp_B(k) + L_B\left(1 - \sum_{k=0}^{L_B-1} p_B(k)\right) \tag{6}$$

E_B depends on D_E and on R_B. R_B needs to be determined to derive an equation for the expected value of E_B. Let $R_B(t)$ denote the number of containers from Basic demand that was not transported on day t-1, in short R_B^t. $E_B(t)$ then becomes:

$$E_B(t) = \max(R_B^t + D_E(t) - C, 0)$$

R_B^t has the Markov property: for a given day t, the state is fully described by R_B^t and is independent from previous states. Therefore, a Markov chain is used to derive the expected value of R_B. With this Markov chain, we can continue to determine the expected revenue for given fixed booking limits.

The probability distribution of E_B can be formulated as:

$$P(E_B = m) = \begin{cases} P(D_E \leq C - R_B^t) & m = 0 \\ P(D_E = C + m - R_B^t) & m > 0 \end{cases} \tag{7}$$

Take m > 0 to find the probability of having any excess demand:

$$P(E_B > 0) = P(D_E > C - R_B^t) \tag{8}$$

Subsequently, we determine the probability distribution of the remaining basic demand for the next day, given the remaining demand of the current day, $P(R_B^{t+1} = j | R_B^t = i)$. We will denote this as $p_{R_B}(i,j)$. Two situations can occur, with excess demand and without excess demand. The transition probabilities are:

$$p_{R_B}(i,j) = P(R_B^{t+1} = j, E_B > 0 \middle| R_B^t = i) + P(R_B^{t+1} = j, E_B = 0 | R_B^t = i) \tag{9}$$

In the situation that excess demand occurs, the new Basic demand is not transported. Therefore, the remaining demand of the next day is equal to the Basic demand of today:

$$p_{R_B}(i,j) = P(D_B = j) \qquad E_B > 0 \tag{10}$$

This combined with the probability of the excess demand, we obtain:

$$P(R_B^{t+1} = j, E_B > 0 \middle| R_B^t = i) = P((D_B = j)P(D_E > C - i) \tag{11}$$

In the situation that there is no excess demand, either all demand is transported or some remaining demand is present for the next day:

$$p_{R_B}(i,j) = \begin{cases} P(D_E + D_B + R_B^t < C) & j = 0 \\ P(D_E + D_B + R_B^t - C = j) & j > 0 \end{cases} \qquad E_B = 0 \tag{12}$$

If there is no excess demand, all of R_B^t is transported. Let S be the number of slots left for transporting D_B. In the case that S ≥ D_B, all demand can be transported. Otherwise S can be denoted as:

$$S = D_B - R_B^{t+1} \tag{13}$$

with probability distribution:

$$P(S = s) = P(D_E + R_B^t = C - s) \tag{14}$$

where $0 \leq s \leq C - R_B^t$. If this distribution is not zero, we have $D_E = C - R_B^t - s \leq C - R_B^t$. From (7), it follows that in these cases there is no excess demand. Using equations (13) and (14) we can rewrite (12) as:

$$P(R_B^{t+1} = j, E_B = 0 \middle| R_B^t = i) = \begin{cases} \sum_{s=0}^{C-i} P(D_E + i = C - s)P(D_B \leq s) & j = 0 \\ \sum_{s=0}^{C-i} P(D_E + i = C - s)P(D_B = s + j) & j > 0 \end{cases} \tag{15}$$

Substituting equations (11) and (15) in (9), we get the general transition probabilities:

$$p_B(i,j) =$$

$$\begin{cases} P(D_B = 0)P(D_E > C - i) + \sum_{s=0}^{C-i} P(D_E + i = C - s)P(D_B \leq s) & j = 0 \\ P(D_B = j)P(D_E > C - i) + \sum_{s=0}^{C-i} P(D_E + i = C - s)P(D_B = s + j) & j > 0 \end{cases} \tag{16}$$

We denote the steady-state distribution of the Markov state R_B as $\pi(j) = P(R_B^{\infty} = j)$, where $\pi(j)$ denotes the probability of J remaining demand for the next day on a day in the long run. To find the distribution of $\pi(j)$, a solution needs to be found for the Markov equilibrium equations:

$$\pi_j = \sum_i \pi_i p_B(i,j) \tag{17}$$

$$\sum_i \pi_i = 1 \tag{18}$$

with $p_B(i,j)$ defined by equation (16). For fixed booking limits, this can be solved by finding a feasible solution to the set of linear equations (17) – (18).

Using the steady state expression π_j for the distribution of R_B in equation (7), we can find the expected value of the excess demand (E_B):

$$P(E_B = m) = \begin{cases} \sum_{q=0}^{L_B} P\,(D_E \leq C - q)\pi_q & m = 0 \\ \sum_{q=0}^{L_B} P(D_E = C + m - q)\pi_q & m > 0 \end{cases} \tag{19}$$

$$(E_B) = mP(E_B = m) = \sum_{m=1}^{L_B} mP(E_B = m) = \sum_{m=1}^{L_B} m \sum_{q=0}^{L_B} P(D_E = C + m - q)\pi_q \tag{20}$$

Finally, the expected revenue J for fixed booking limits L_E and L_B can be determined using the expressions for the expected demand (5) – (6) and the expected excess demand in the objective function (4).

4 METHODOLOGY

With the derivation in the previous section, the CFCM(1,1,2) model becomes:

$$\max_{L_E, L_B} J = f_{\mathrm{E}}\,(D_E) + f_{\mathrm{B}}\,(D_{\mathrm{B}}) - p\mathbb{E}(\mathrm{E_B})$$

where

$$\mathbb{E}(D_E) = \sum_{k=1}^{L_E - 1} k p_E(k) + L_E\left(1 - \sum_{k=0}^{L_E - 1} p_E(k)\right)$$

$$\mathbb{E}(D_B) = \sum_{l=1}^{L_B - 1} l p_B(l) + L_B\left(1 - \sum_{l=0}^{L_B - 1} p_B(l)\right)$$

$$\mathbb{E}(E_B) = \sum_{m=1}^{L_B} m \sum_{q=0}^{L_B} P(D_E = C + m - q)\pi_q$$

subject to:

$$\pi_0 = \sum_{i=0}^{L_B} \pi_i [P(D_B = 0)P(D_E > C - i) + \sum_{s=0}^{C-i} P(D_E + i = C - s)P(D_B \leq s)]$$

$$\pi_j = \sum_{i=0}^{L_B} \pi_i [P(D_B = j)P(D_E > C - i) + \sum_{s=0}^{C-i} P(D_E + i = C - s)P(D_B = s + j)], (j > 0)$$

$$\sum_{i=0}^{L_B} \pi_i = 1$$

$$L_E, L_B \in \mathbb{N}$$

$$\pi_q \geq 0$$

Using these formulas, a grid search will be done to determine the booking limits where the revenue is maximized. With fixed booking limits L_E and L_B the problem reduces to solving a linear programming problem with equations (17) - (18). The maximum expected revenue J is then easy to determine, leading to the optimal set of booking limits.

A sensitivity analysis will be applied to determine which parameters have a big influence on the outcome of the model. The analysis will be done in two ways, one analysis where the booking limits are adjusted by the change of the parameters and one where the booking limits are set beforehand. The first approach, where the booking limits are adjusted, will show what the influence in the revenue would be in multiple cases with different parameters. This analysis will be done by using the one-factor-at-a-time (OFAT) approach, as is described in Van Griensven *et al* (2006). This method consists of changing one parameter at a time while the rest of the parameters are fixed. This will be repeated for every parameter. The second, with fixed booking limits, will be done with differentiating the demand of Express and Basic. This analysis shows the influence on the expected revenue if the demand is different than initially expected. Here both the change in demand for Express and Basic are taken into account.

In the next section the framework of the different outcomes will be provided for multiple cases of the problem. The revenue will be compared to cases where the CFCM problem is not used. For example a case of the problem will be, instead of using CFCM(1,1,2), only basic or only express transportation is provided. Thereafter, the sensitivity analysis will be applied.

5 CASE STUDY AND RESULTS

In this section the results of different CFCM(1,1,2) scenarios are presented. First, the CFCM model is compared to traditional methods, where the results of the methods are studied. Thereafter, more CFCM problems with other capacities will be compared to a traditional method. Last, the sensitivity analysis is done that consists of two parts.

5.1 COMPARISON WITH TRADITIONAL METHODS

First, we will compare the CFCM(1,1,2) model with alternative methods. Some of the alternative methods that can be used by transportation providers are:

- Offering only one kind of service.
- Offering Basic service with the possibility that the Basic service can be substituted with Express service.
- Offering both, but putting no booking limit on Express, the Express demand will be accepted up to the capacity C.
- Offering both, but putting no booking limit on Basic, the Basic demand will be accepted up to the capacity 2*C.

In table 1 the overview of the different case studies are provided, where the CFCM(1,1,2) model can be compared to the alternative methods.

For a reference of the transport costs per container, in the paper of Luo (2002) costs of $200 are used, this is equivalent to approximately €170. Assuming this is for Basic service, the fare for Express service is chosen to be €200. The penalty should always be higher than the tariff, hence an amount of €275 is selected.

In the paper of Woodburn (2011) an analysis is done on the mean capacity of container trains in Great Britain. The mean of the capacity is around 60 slots. Therefore, in the calculation we will use this number.

The demand is not certain, but it is chosen in a way that the average daily demand is higher than the capacity. In this case the model needs to find a trade-off between the two fare classes.

Table 1 Case studies of CFCM(1,1,2) model compared with alternative methods

Case	Capacity C	Demand Express	Demand Basic	Fare $(f_E; f_B)$	Penalty p
CFCM(1,1,2)	60	Poisson(45)	Poisson(45)	200;170	275
Basic service only	60	0	Poisson(45)	200;170	275
Express service only	60	Poisson(45)	0	200;170	275
Basic service with substitution	60	0	Poisson(90)	200;170	275
No limit on Express	60	Poisson(45)	Poisson(45)	200;170	275
No limit on basic	60	Poisson(45)	Poisson(45)	200;170	275

In table 2 an overview of the results is shown. The table contains for each of the experiments the optimal booking limits, the expected revenue, the capacity utilisation, the expected excess and the computing time. The expected capacity utilisation η is computed by:

$$\eta = \frac{E(D_E) + E(D_B)}{C}$$

Table 2 Results of case studies in table 1

Case	Booking limits $L_E; L_B$	Expected revenue J	Capacity utilisation η [%]	Expected excess $E(E_B)$	Comp. Time T[m]
CFCM(1,1,2)	45;18	11377.8	100.0	0.5	19.8
Basic service only	-;120	7650.0	75.0	0.0	0.3
Express service only	60;-	8991.6	74.9	0.0	0.1
Basic service with substitution	-;120	10199.9	100.0	0.0	0.2
No limit on Express	(60);16	11304.9	101.6	1.5	0.6
No limit on basic	16;(120)	10545.5	101.7	1.1	0.5

The results show that the CFCM(1,1,2) model can significantly increase the expected revenue in comparison to the traditional methods. Also in the cases that only one of the services is provided, the capacity utilisation drops significantly.

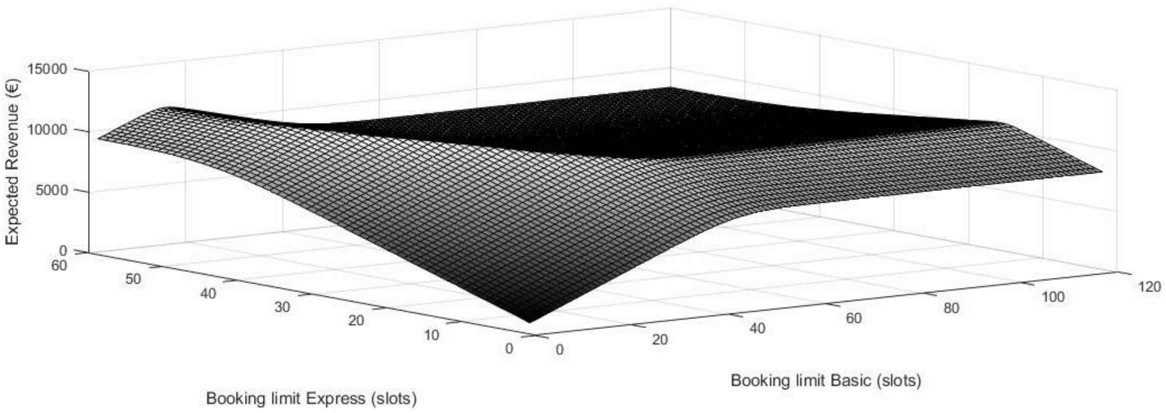

Figure 1: 3D plot of grid search for CFCM(1,1,2) model

Figure 1 shows a 3D plot of the revenues of the grid search for the CFCM(1,1,2) problem stated in table 1. This figure shows the expected revenue for every combination of booking limits. For high booking limits of L_E and L_B the revenue drops. The reason for this is if the accepted demand is higher than the amount of demand that can be shipped, a penalty needs to be paid for every excess demand.

To verify whether the expected revenue of the CFCM model is also higher than the expected revenue of other traditional methods with other capacities, we will look at multiple cases of the CFCM(1,1,2) model. The mean of the demand for Express and the mean of the demand for Basic will be denoted as μ_E and μ_B. Because the expected revenue for *no limit on express* is the highest of the traditional alternatives for CFCM in table 2, the next cases will be compared to the cases where there is *no limit on express* to check whether the expected revenue for CFCM will still be higher. The setup of this experiment is stated in table 3 and the results in table 4.

Table 3 Case studies of different CFCM(1,1,2) models

Case	**Capacity C**	**Demand Express**	**Demand Basic**	**Fare ($f_E; f_B$)**	**Penalty p**
C=10; $\mu_E = 8; \mu_B = 5$	10	Poisson(8)	Poisson(5)	200;170	275
C=30; $\mu_E = 15; \mu_B = 20$	30	Poisson(15)	Poisson(20)	200;170	275
C=50; $\mu_E = 40; \mu_B = 20$	50	Poisson(40)	Poisson(20)	200;170	275
C=80; $\mu_E = 60; \mu_B = 40$	80	Poisson(60)	Poisson(40)	200;170	275

Table 4 Results of case studies in table 3

Case	Booking limits $L_E; L_B$	Expected revenue J	Capacity utilisation η [%]	Expected excess $E(E_B)$	Comp. Time T[m]
C=10; $\mu_E = 8; \mu_B = 5$	7;4	1834.7	99.0	0.1	0.1
No limit on Express	10;3	1799.1	104.0	0.7	0.04
C=30; $\mu_E = 15; \mu_B = 20$	18;16	5459.0	100.3	0.3	2.1
No limit on Express	30;16	5440.5	102.0	0.8	0.16
C=50; $\mu_E = 40; \mu_B = 20$	39;13	9519.7	99.8	0.3	10.4
No limit on Express	50;11	9429.1	101.6	1.5	0.40
C=80; $\mu_E = 60; \mu_B = 40$	60;23	15210.4	99.9	0.3	57.1
No limit on Express	80;21	15138.9	101.2	1.6	1.14

Looking at the results of the comparison to the *no limit on express* method, the expected revenue of the CFCM model is always higher. In the first case, the expected revenue is increased by 2.0%. The expected excess for the CFCM model is also lower than for the *no limit on express* method. Therefore, the cargo for the Basic transport customers are more often not able to be shipped.

5.2 Sensitivity Analysis

In the original research of Van Riessen *et al* (2015) the use of variation in input parameters is limited. In this section a parameter analysis of the model will be performed. In the analysis we recalculate the model with multiple parameters. With the analysis we check which parameters of the model have a big influence on the output of the model. If parameters might differ in real-life cases, the analysis will show the effect it has on the revenue. The analysis will be done using two different approaches.

5.2.1 Sensitivity Analysis Approach One

A sensitivity analyses is done based on the one-factor-at-a-time (OFAT) approach, changing one parameter at a time while the rest of the parameters are fixed. The booking limits are not set beforehand in this analyses. Most parameters are fixed and known, for example the capacity. Therefor, there is no need to take other values into account when determining the optimal booking limits. The capacity, the demands for the different transport methods, the fares and the penalty will be varied. The variation is based on a percentage deviation from the nominal values.

In figure 2 and figure 3 spiderplots are shown for a capacity of 30 and 60. The spiderplots, as described in Eschenbach (1992), show the relationship between the parameters and the output, with a percentage deviation of the parameters. The center of the spiderplot is the base case, where the nominal values of the parameters are used. The nominal values for the parameters are shown in table 5.

The booking limits are not fixed, for every change in a parameter the model has been run to find the optimal booking limits.

Table 5 Nominal values for parameter analysis

Case	Capacity C	Demand Express	Demand Basic	Fare $(f_E; f_B)$	Penalty p
1.	60	Poisson(40)	Poisson(40)	200;170	275
2.	30	Poisson(20)	Poisson(20)	200;170	275

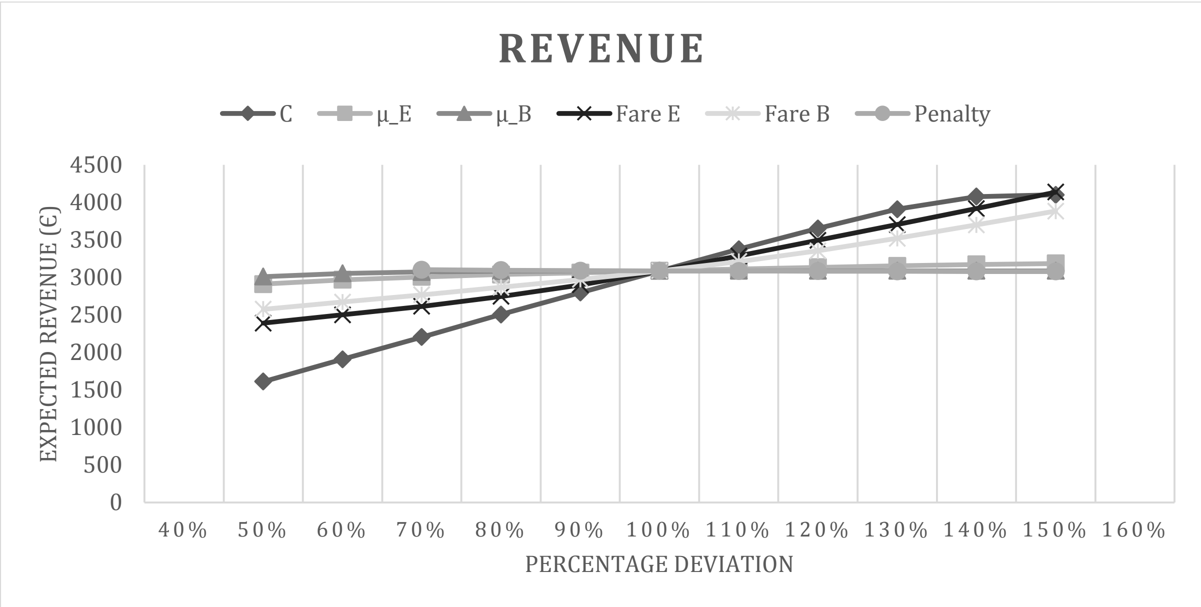

Figure 2: Spiderplot for capacity of 30

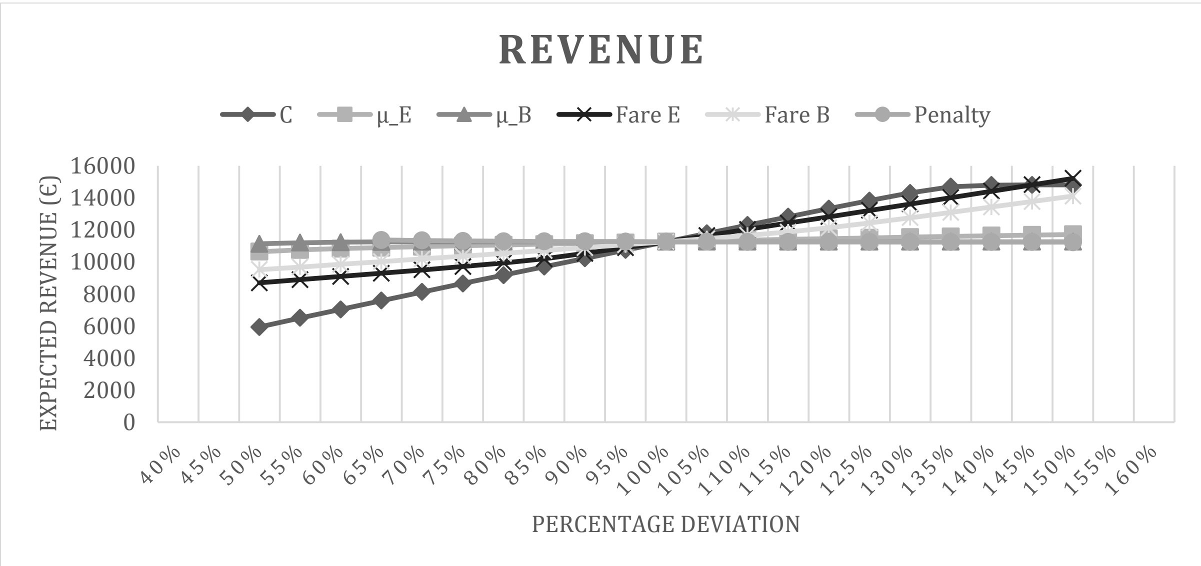

Figure 3: Spiderplot for capacity of 60

In the spiderplots it is shown that the revenue is not very sensitive to changes in μ_E and μ_B. Also changes in the penalty will not influence the revenue very much. The fares for E and B will influence the revenue on a linear level. The capacity will also change the revenue on a linear level, but after a big increase of the capacity, the revenue does not increase anymore. This is expected, because if the capacity is too high, the demand for transportation is not big enough to fill all the slots.

5.2.2 Sensitivity Analysis Approach Two

Because the distribution of the demand is uncertain and can differ from the expected demand, a risk analysis should be performed for this parameter. The optimal booking limits are determined beforehand. In this case the analyses are done based on the optimal booking limits for the case in table 5 with a capacity of 30. The optimal booking limits are 20 for Express and 12 for Basic and the expected revenue is around 3080 euros. In figure 4 the outcomes are shown for this analysis. The demand of Basic and Express is varied between Poisson(5) and Poisson(30).

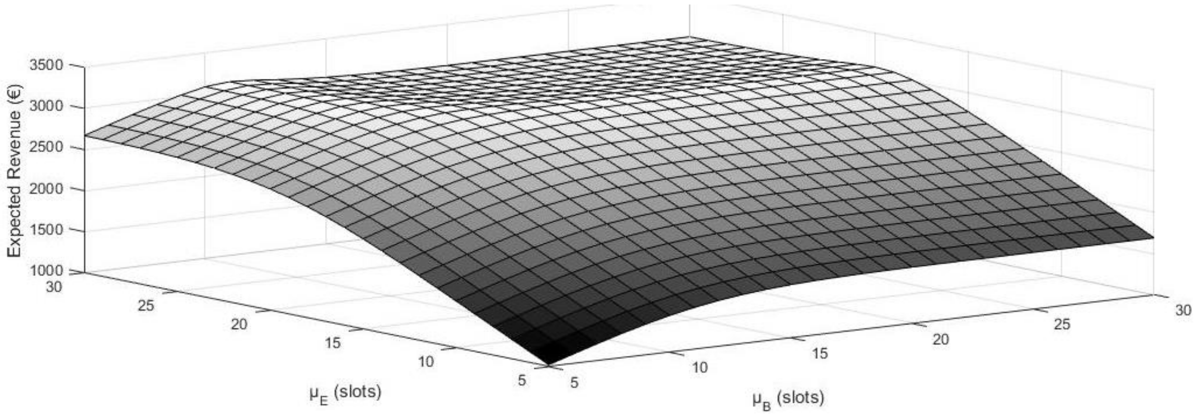

Figure 4 Sensitivity analysis with fixed booking limits for C=30

Looking at these graphs, the expected revenue with fixed booking limits is not very sensitive to the demand of Basic. The revenue is on the other hand sensitive to decrease of the demand of Express. The revenue drops significantly if the demand of Express drops. For a high demand of Express and a high demand of Basic, the revenue also drops slightly. This is due to the penalty of the expected excess. The booking limits in this case are set for a μ_E and μ_B of 20, where the limits are chosen higher than the capacity, because the demand for Basic can also be shipped on the second day. If the demand is higher, the expected excess will increase, which causes in a higher penalty. In figure 5 the expected excess is shown for the analysis.

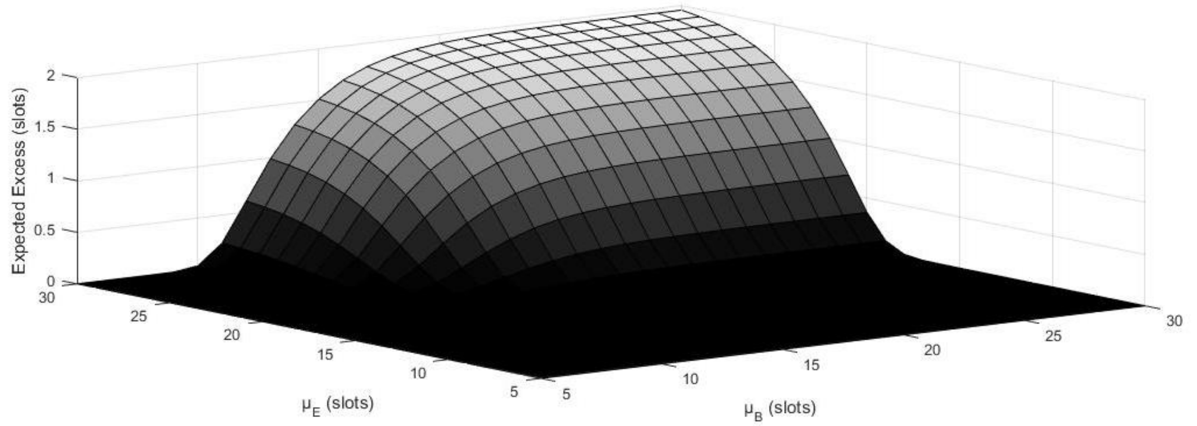

Figure 5 Expected excess for sensitivity analysis for C=30

6 Summary and Recommendations

In this paper the Cargo Fare Class Mix (CFCM) problem of Van Riessen *et al* (2015) is studied. The CFCM(1,1,2) model considers one route, one destination and two fare classes. This model can be used for intermodal networks for container transportation where multiple services with different delivery deadlines are offered. The paper focuses on the revenue management of the transportation. The main goal of the problem is to find the correct balance between offering one fare class against the other so that the revenue can be increased.

In the results section it is shown that for the case studies the expected revenue for the CFCM approach is higher than the expected revenues in other traditional methods. The *no limit on express* method seems to compete with the CFCM method, but comparing multiple scenarios with the two methods, the expected revenue for the CFCM model stays higher than the one of *no limit on express* method.

Two parameter sensitivity analyses are applied to the model. The first analysis is based on the one-factor-at-a-time (OFAT) approach where one parameter will be changed while the other parameters are fixed at their nominal values. This is repeated for all the parameters. The analysis shows that for changes in μ_E and μ_B the revenue will not change much if the booking limits can be matched to the changes in the μ's. In the second analyses it shows that when the booking limits are set beforehand and the demand of Express service is less than expected, there will be a significant decrease in the revenue. From these results it seems that it is better to therefor underestimate the demand for Express than to overestimate it.

In further research it will be useful to provide a model that is applicable for more routes, destinations and fare classes. Also the sensitivity analyses can be extended: instead of using a one-factor-at-a-time method, a method can be used that handles multiple factors simultaneously. In this way the sensitivity can be checked in a case that multiple parameters are changing. The correlation of the different parameters can cause a different sensitivity, which is not checked with the OFAT method.

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