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Type Ⅱ Errors of Demerit Control Charts

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Abstract

- A demerit control chart is a useful tool for monitoring different types of defects in a single chart while taking into account different levels of severity.
- Control limits were improved upon by approaches to finding the exact distribution of the demerit statistic and establishing probability-based limits.
- Now, again with exact distributions, we consider Type Ⅱ errors as well when establishing control limits for different shifts, means and weights.

Introduction

- Complex products may present more than one type of defect, and these defects are classified according to their seriousness and effect on product quality and performance.

- There are several classifications of defects in the literature, the following classification was defined:

- Case A (Very Serious):

  The unit is either completely unfit for service or will cause personal injury or property damage.

- Case B (Serious):

  The unit will possibly suffer a Class A operating failure or will certainly have reduced life or increased maintenance cost.

- Case C (Moderately Serious):

  The unit will possibly fail in service or have a major defect in finish or quality of work.

- Case D (Minor):

  The unit will not fail in service but has minor defects in finish or quality of work.

- The weights should be determined by each organization according to the effect of each type of defect on the product's performance and quality.
- Seriousness depends fundamentally upon the evaluation of the loss or expense that would be incurred by using the defective unit.

Methods

- Observations were based on exact probabilities associated with linear combinations of Poisson random variables.

- Means and weights used in the present work are those used by Jones et al. and Ho et al.

Jones et al. (1999) Means and Weights

	Class A	Class B	Class C	Class D
Means	0.3248	0.7888	4.756	2.2504
Weights	100	50	10	1

Juran and Godfrey (JG) (1999) and Grant and Leavenworth (GL) (1996) Weights

	Class A	Class B	Class C	Class D
JG (1951)	100	75	25	5
GL (1996)	100	40	20	1

Ho et al. (2003) Means and Weights

	Class A	Class B	Class C	Class D
Means	0.3098535	1.0844955	4.4154825	2.0140725
Weights (Set 1)	100	50	10	1
Weights (Set 2)	60	50	10	1

- Considering these shifts, the demerit statistic for Poisson random, variables can be represented as follows where D=Demerit:

$$D = w_1(\lambda_1 + \delta\sqrt{\lambda_1}) + w_2(\lambda_2 + \delta\sqrt{\lambda_2}) + w_3(\lambda_3 + \delta\sqrt{\lambda_3}) + w_4(\lambda_4 + \delta\sqrt{\lambda_4})$$

- As D gets larger, the possible combinations associated with it become relatively many.

Scenarios to Study Type II Error Probabilities

Scenario	Means (λ)	Weights (w)	Shifts in the means (δ)
1	Jones	Jones	0.125, 0.25, 0.50, 1.00, 2.00, 3.00
2	Jones	Juran	0.125, 0.25, 0.50, 1.00, 2.00, 3.00
3	Jones	Grant and Leavenworth	0.125, 0.25, 0.50, 1.00, 2.00, 3.00
4	Ho	Ho (Set 1)	0.125, 0.25, 0.50, 1.00, 2.00, 3.00
5	Ho	Ho (Set 2)	0.125, 0.25, 0.50, 1.00, 2.00, 3.00
6	Ho	Juran	0.125, 0.25, 0.50, 1.00, 2.00, 3.00
7	Ho	Grant and Leavenworth	0.125, 0.25, 0.50, 1.00, 2.00, 3.00

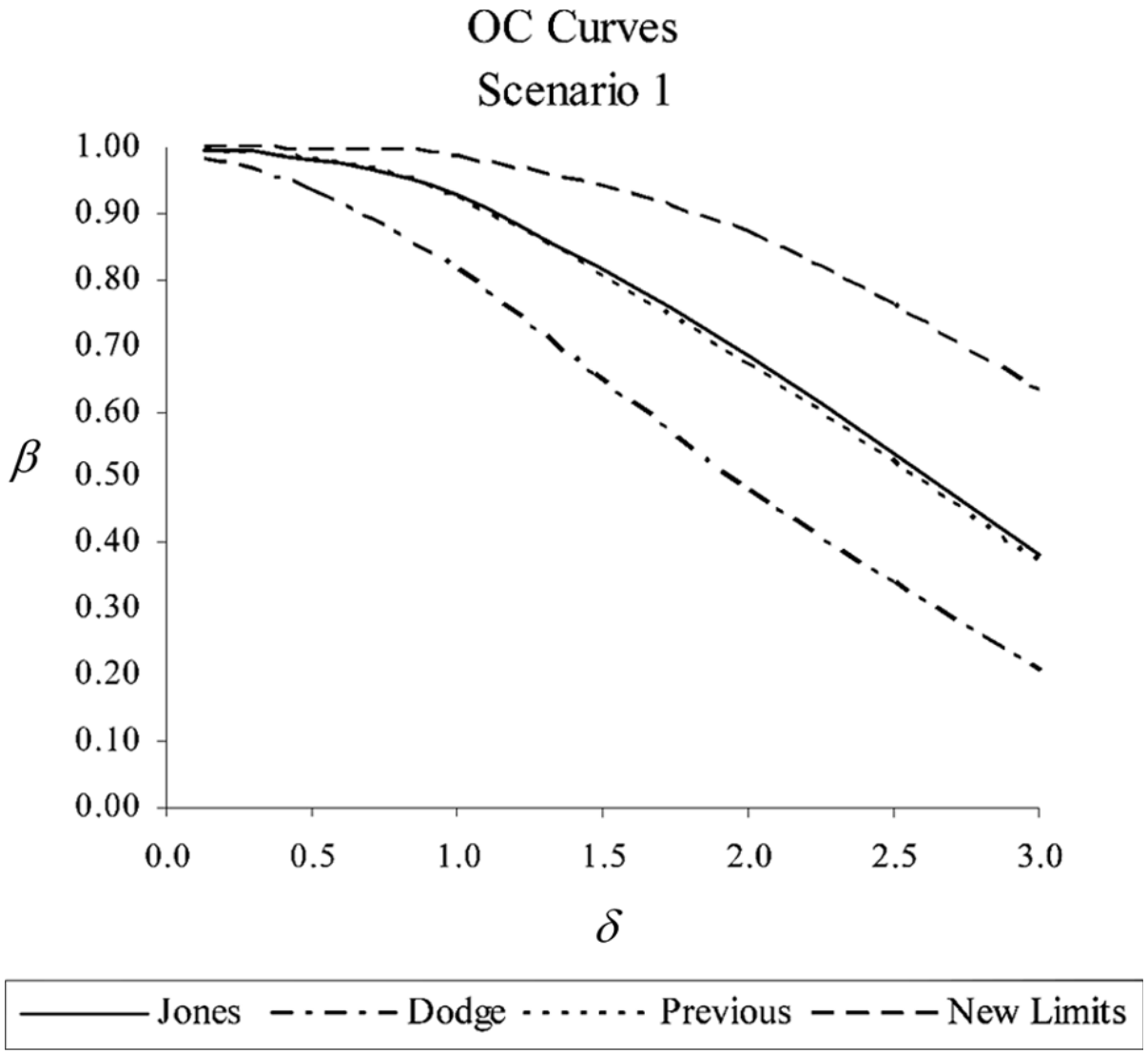
Results According to Control Limits

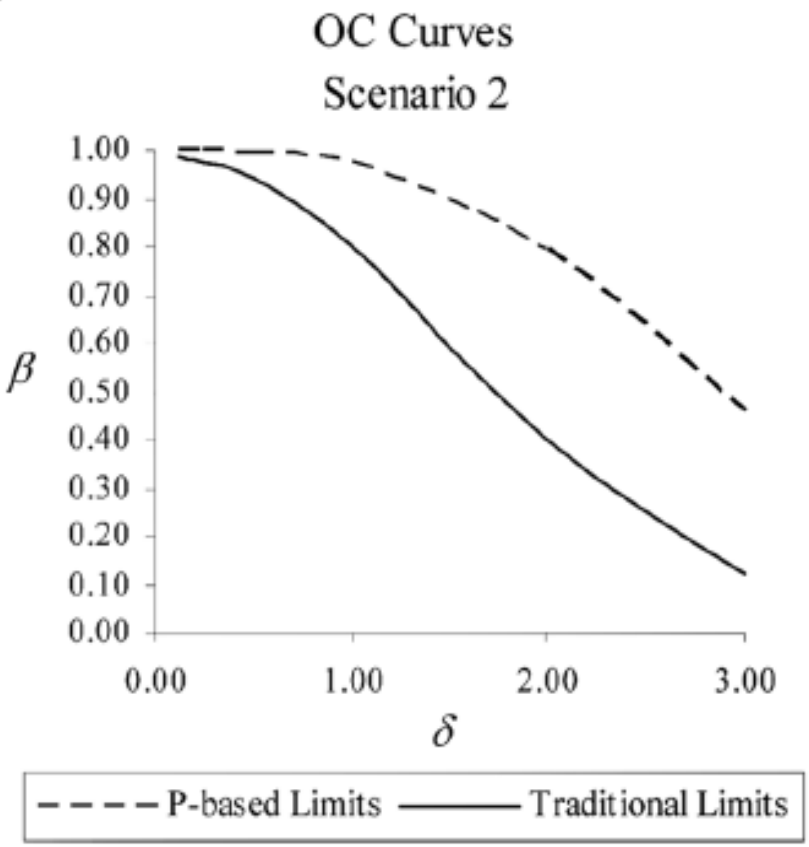
Upper and Lower Control Limits Compared for Scenario 1

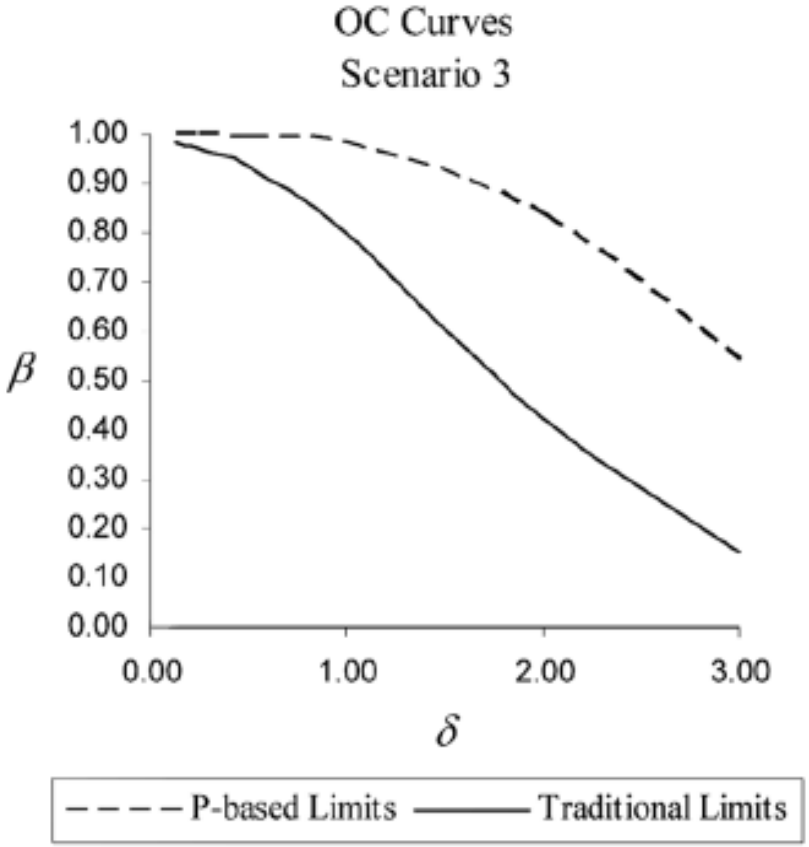
Scenario 1	Jones	Dodge	Previous	New limits
UCL	431	348	425	543
LCL	2	0	2	5
P	0.002554815	0.009933760	0.002685506	0.002699550

Comparison of Type II Errors, Scenario 1

	β			
δ	Jones	Dodge	Previous	New limits
Scenario 1				
0.125	0.99598	0.98173	0.99574	0.99812
0.25	0.99302	0.96981	0.99263	0.99838
0.5	0.98131	0.93395	0.98046	0.99718
1.0	0.92606	0.81455	0.92338	0.98407
2.0	0.68191	0.47857	0.67167	0.87162
3.0	0.38266	0.20665	0.36808	0.63310


OC Curves
Scenario 1
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
β
0.0
0.5
1.0
1.5
2.0
2.5
3.0
δ
Jones
Dodge
Previous
New Limits


OC Curves
Scenario 2
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
β
0.00
1.00
2.00
3.00
δ
P-based Limits
Traditional Limits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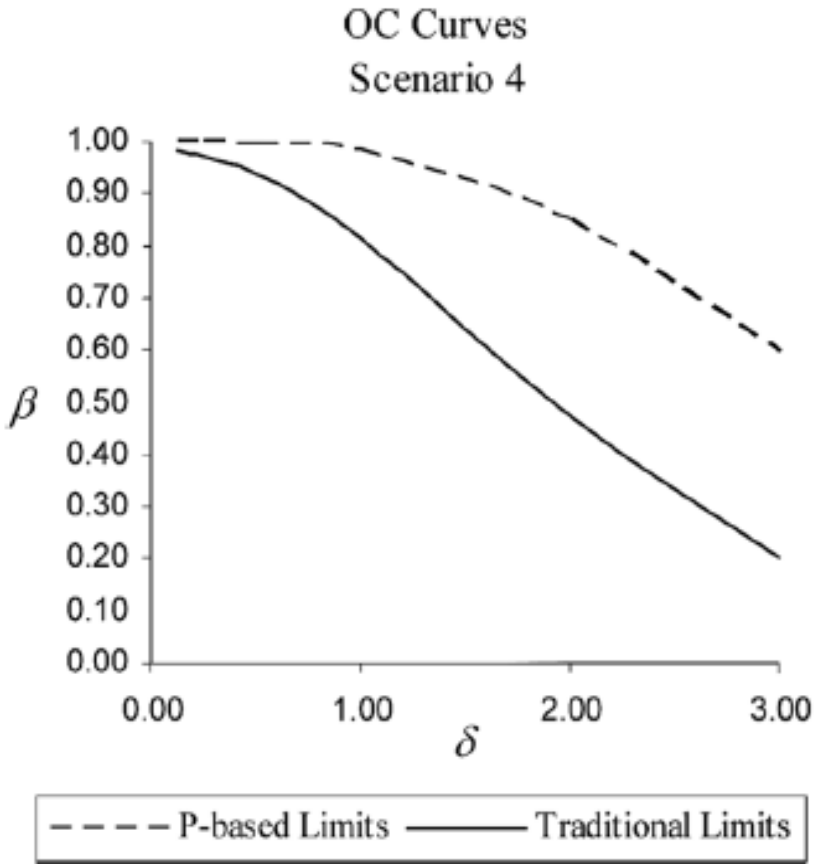
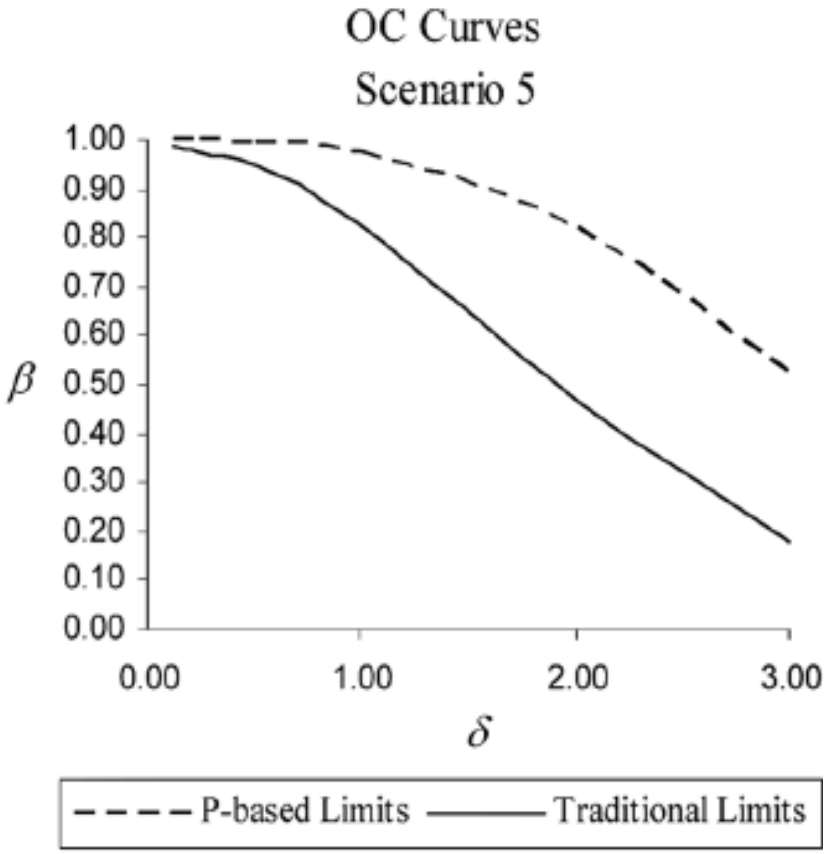
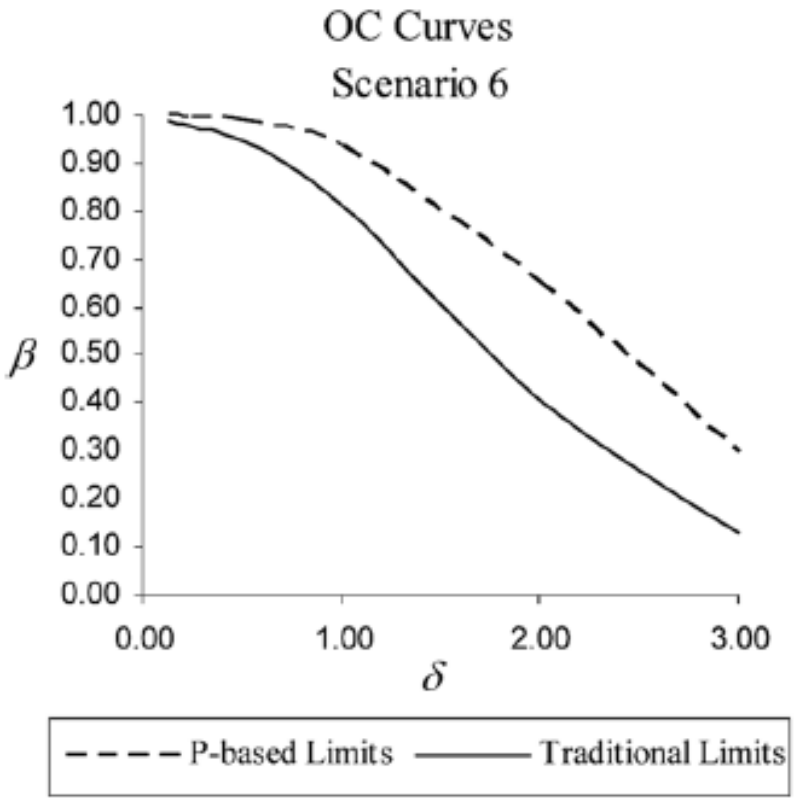
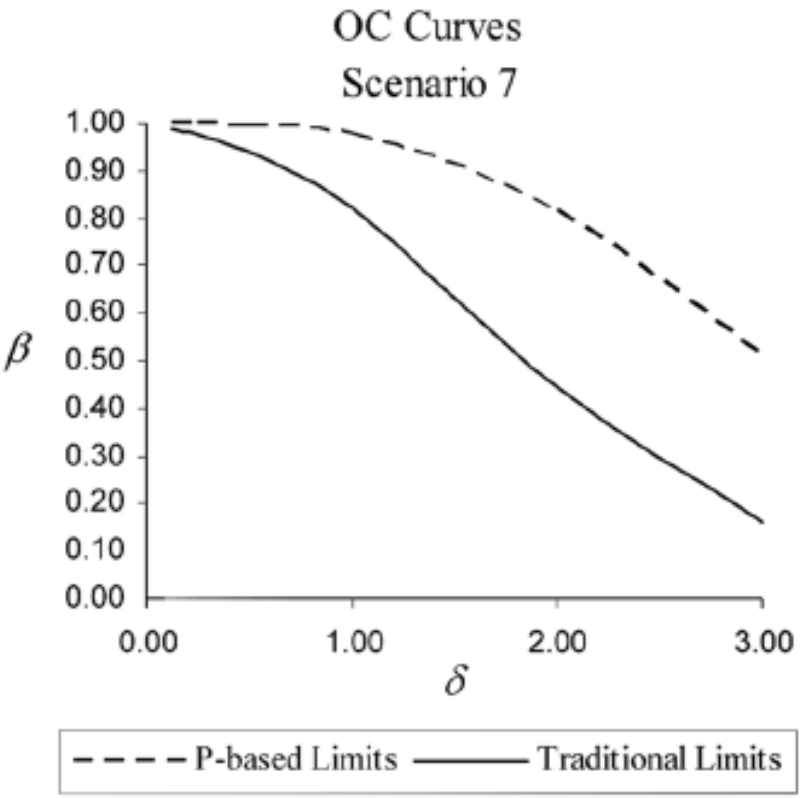
Scenario 3
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
β
0.00
1.00
2.00
3.00
δ
P-based Limits
Traditional Limits


OC Curves
Scenario 4
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
β
0.00
1.00
2.00
3.00
δ
P-based Limits
Traditional Limits


OC Curves
Scenario 5
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
β
0.00
1.00
2.00
3.00
δ
P-based Limits
Traditional Limits


OC Curves
Scenario 6
1.00
0.90
0.80
0.70
0.60
β 0.50
0.40
0.30
0.20
0.10
0.00
0.00
1.00
2.00
3.00
δ
P-based Limits
Traditional Limits


OC Curves
Scenario 7
1.00
0.90
0.80
0.70
0.60
β 0.50
0.40
0.30
0.20
0.10
0.00
0.00
1.00
2.00
3.00
δ
P-based Limits
Traditional Limits

Results According to Means and Weights

Group 1 Comparison of Type II Errors, Traditional and Probability-Based Limits

	β					
	Traditional limits			P-based limits		
Group 1	Scenario			Scenario		
δ	1	2	3	1	2	3
0.125	0.98173	0.98651	0.98323	0.99812	0.99811	0.99812
0.25	0.96981	0.97585	0.97130	0.99838	0.99831	0.99835
0.5	0.93395	0.93987	0.93352	0.99718	0.99659	0.99696
1	0.81455	0.80224	0.80034	0.98407	0.97668	0.98123
2	0.47857	0.39766	0.42463	0.87162	0.79465	0.83755
3	0.20665	0.12361	0.15276	0.63310	0.45722	0.54394

Group 2 Comparison of Type II Errors, Traditional and Probability-Based Limits

Group 2	β							
	Traditional limits				P-based limits			
	Scenario				Scenario			
δ	4	5	6	7	4	5	6	7
0.125	0.98294	0.98694	0.98772	0.98592	0.99809	0.99808	0.99714	0.99809
0.25	0.97158	0.97752	0.97795	0.97561	0.99823	0.99821	0.99572	0.99821
0.5	0.93681	0.94664	0.94433	0.94228	0.99651	0.99631	0.98764	0.99622
1	0.81787	0.83011	0.81167	0.81945	0.98030	0.97746	0.93633	0.97667
2	0.47608	0.46633	0.42794	0.44666	0.85110	0.81986	0.64851	0.81363
3	0.20092	0.17857	0.12824	0.15991	0.59370	0.52207	0.29464	0.50697

Conclusion

Recommended Upper and Lower Control Limits for Scenarios 1 Through 7

Scenario	LCL	UCL
1	5	543
2	25	740
3	5	584
4	4	551
5	4	442
6	15	680
7	4	582