

Simulation Results of the Paper entitled “The Design of a Zone-Picking System with Cooperation Area between Neighboring Zones and Its Cooperation Methods” (submitted to International Journal of Production Research)

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Table 2. The Duncan test results on the TST performance of similarity coefficients.

Similarity Coefficient ($\alpha = 0.05$)	Subset		
	1	2	3
OSC	168.04		
SSC		179.01	
BSC			183.59

	Clustering Method		
	Cumulative Seed	Fuzzy C-Means	Random
Similarity Coefficient	OSC] SSC] BSC]	BSC] SSC] OSC]	OSC] SSC] BSC]

	Storage Assignment Method			
	Vertical Assignment	Horizontal Assignment	Center-of-Order-Gravity	Random Assignment
Similarity Coefficient	BSC] SSC] OSC]	OSC] SSC] BSC]	SSC] OSC] BSC]	OSC] BSC] SSC]

	Cooperation-Area Design Method				
	Vertical	Horizontal	Hybrid	Diagonal	No Cooperation Area
Similarity Coefficient	OSC] SSC] BSC]	OSC] SSC] BSC]	OSC] SSC] BSC]	OSC] SSC] BSC]	OSC] SSC] BSC]

	Cooperation Method					
	Always Help	RPTR(1.5)	RPTR(2.0)	RNIR(1.5)	RNIR(2.0)	No Cooperation
Similarity Coefficient	OSC] SSC] BSC]	OSC] SSC] BSC]	OSC] SSC] BSC]	OSC] SSC] BSC]	OSC] SSC] BSC]	OSC] SSC] BSC]

Note: Similarity coefficients connected symbolically are not significantly different at an α of 0.05.

Figure 4. The Duncan-test results on the TST performance of similarity coefficients under different levels of the other four factors.

Table 3. The Duncan test results on the TST performance of clustering methods.

Clustering Method ($\alpha = 0.05$)	Subset		
	1	2	3
Fuzzy C-Means	140.97	173.76	215.92
Cumulative Seed			
Random			

	Similarity Coefficient		
	OSC	BSC	SSC
Clustering Method	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Cumulative Seed] Random]

	Storage Assignment Method			
	Vertical Assignment	Horizontal Assignment	Center-of-Order-Gravity	Random Assignment
Clustering Method	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Random] Cumulative Seed]	Cumulative Seed] Fuzzy C-Means] Random]	Fuzzy C-Means] Cumulative Seed] Random]

	Cooperation-Area Design Method		
	Vertical	Horizontal	Hybrid
Clustering Method	Fuzzy C-Means] Cumulative Seed] Random]	Cumulative Seed] Fuzzy C-Means] Random]	Fuzzy C-Means] Cumulative Seed] Random]

	Cooperation-Area Design Method	
	Diagonal	No Cooperation Area
Clustering Method	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Cumulative Seed] Random]

	Cooperation Method		
	Always Help	RPTR(1.5)	RPTR(2.0)
Clustering Method	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Cumulative Seed] Random]

	Cooperation Method		
	RNIR(1.5)	RNIR(2.0)	No Cooperation
Clustering Method	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Cumulative Seed] Random]	Fuzzy C-Means] Cumulative Seed] Random]

Note: Clustering methods connected symbolically are not significantly different at an α of 0.05.

Figure 5. The Duncan-test results on the TST performance of clustering methods under different levels of the other four factors.

Table 4. The Duncan test results on the TST performance of storage assignment methods.

Storage Assignment Method ($\alpha = 0.05$)	Subset			
	1	2	3	4
Center-of-Order-Gravity	126.83			
Vertical Assignment		157.78		
Horizontal Assignment			168.24	
Random Assignment				254.68

	Similarity Coefficient		
	OSC	BSC	SSC
Storage Assignment Method	Center-of-Order-Gravity Horizontal Assignment Vertical Assignment Random Assignment	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment
	Clustering Method		
	Cumulative Seed	Fuzzy C-Means	Random
Storage Assignment Method	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Vertical Assignment Center-of-Order-Gravity Horizontal Assignment Random Assignment	Center-of-Order-Gravity Horizontal Assignment Vertical Assignment Random Assignment
	Cooperation-Area Design Method		
	Vertical	Horizontal	Hybrid
Storage Assignment Method	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment
	Cooperation-Area Design Method		
	Diagonal	No Cooperation Area	
Storage Assignment Method	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Horizontal Assignment Vertical Assignment Random Assignment	
	Cooperation Method		
	Always Help	RPTR(1.5)	RPTR(2.0)
Storage Assignment Method	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment
	Cooperation Method		
	RNIR(1.5)	RNIR(2.0)	No Cooperation
Storage Assignment Method	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Vertical Assignment Horizontal Assignment Random Assignment	Center-of-Order-Gravity Horizontal Assignment Vertical Assignment Random Assignment

Note: Storage assignment methods connected symbolically are not significantly different at an α of 0.05.

Figure 6. The Duncan-test results on the TST performance of storage assignment methods under different levels of the other four factors.

Table 5. The Duncan test results on the TST performance of cooperation-area design methods.

Cooperation-Area Design Method ($\alpha = 0.05$)	Subset			
	1	2	3	4
Diagonal	174.40			
Hybrid		175.46		
Horizontal		175.62		
Vertical			176.87	
No Cooperation Area				182.05

Similarity Coefficient				
Cooperation-Area Design Method	OSC	BSC	SSC	
	Diagonal Horizontal Hybrid Vertical No Cooperation Area	Diagonal Hybrid Horizontal Vertical No Cooperation Area	Diagonal Horizontal Hybrid Vertical No Cooperation Area	
Clustering Method				
Cooperation-Area Design Method	Cumulative Seed	Fuzzy C-Means	Random	
	Diagonal Hybrid Vertical Horizontal No Cooperation Area	Diagonal Hybrid Vertical No Cooperation Area Horizontal	Horizontal Diagonal Hybrid Vertical No Cooperation Area	
Storage Assignment Method				
Cooperation-Area Design Method	Vertical Assignment	Horizontal Assignment	Center-of-Order-Gravity	Random Assignment
	Horizontal Diagonal Hybrid Vertical No Cooperation Area	Diagonal Horizontal Hybrid Vertical No Cooperation Area	Diagonal Horizontal Hybrid Vertical No Cooperation Area	Diagonal Hybrid Vertical Horizontal No Cooperation Area
Cooperation Method				
Cooperation-Area Design Method	Always Help	RPTR(1.5)	RPTR(2.0)	
	Diagonal Hybrid Horizontal Vertical No Cooperation Area	Diagonal Horizontal Hybrid Vertical No Cooperation Area	Diagonal Hybrid Horizontal Vertical No Cooperation Area	
Cooperation Method				
Cooperation-Area Design Method	RNIR(1.5)	RNIR(2.0)	No Cooperation	
	Diagonal Horizontal Hybrid Vertical No Cooperation Area	Diagonal Horizontal Hybrid Vertical No Cooperation Area	Diagonal Hybrid Horizontal Vertical No Cooperation Area	

Note: Cooperation-area design methods connected symbolically are not significantly different at an α of 0.05.

Figure 7. The Duncan-test results on the TST performance of cooperation-area design methods under different levels of the other four factors.

Table 6. The Duncan test results on the TST performance of cooperation methods.

Cooperation Method ($\alpha = 0.05$)	Subset			
	1	2	3	4
RNIR(1.5)	172.33			
RPTR(1.5)	172.40			
RPTR(2.0)		174.55		
RNIR(2.0)			177.81	
No Cooperation				182.05
Always Help				182.14

		Similarity Coefficient						
		OSC	BSC	SSC				
Cooperation Method	RNIR(1.5)	RPTR(1.5) RNIR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)				
	Always Help				No Cooperation	No Cooperation		
	No Cooperation				Always Help	Always Help		
Clustering Method								
		Cumulative Seed	Fuzzy C-Means	Random				
Cooperation Method	RPTR(1.5)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)	RPTR(1.5) RNIR(1.5) RPTR(2.0) RNIR(2.0)				
	RNIR(1.5)				No Cooperation	Always Help		
	RPTR(2.0)				Always Help	No Cooperation		
	RNIR(2.0)				No Cooperation	No Cooperation		
	Always Help							
	No Cooperation							
Storage Assignment Method								
		Vertical Assignment	Horizontal Assignment	Center-of-Order-Gravity	Random Assignment			
Cooperation Method	RPTR(1.5)	RNIR(1.5) RNIR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)			
	Always Help					No Cooperation	Always Help	Always Help
	No Cooperation					Always Help	No Cooperation	No Cooperation
Cooperation-Area Design Method								
		Vertical	Horizontal	Hybrid				
Cooperation Method	RPTR(1.5)	RNIR(1.5) RNIR(1.5) RPTR(2.0) RNIR(2.0)	RPTR(1.5) RNIR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)			
	No Cooperation					No Cooperation	No Cooperation	
	Always Help					Always Help	Always Help	
Cooperation-Area Design Method								
		Diagonal		No Cooperation Area				
Cooperation Method	RNIR(1.5)	RNIR(1.5) RPTR(1.5) RPTR(2.0) RNIR(2.0)		RPTR(1.5) RNIR(1.5) RPTR(2.0) RNIR(2.0)				
	Always Help					Always Help		
	No Cooperation					No Cooperation		

Note: Cooperation methods connected symbolically are not significantly different at an α of 0.05.

Figure 8. The Duncan-test results on the TST performance of cooperation methods under different levels of the other four factors.