Evaluation of Request Order Decision Strategy in the Selection of Substitute Employees for Shift Management Tasks

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The Thirteenth International Conference on Intelligent Systems and Applications
INTELLI 2024
March 12, 2024, 12:30 - 14:00, Athens, Greece

HOKKAIDO UNIVERSITY

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Self Introduction

- Name
  - Tomoya Chisaka
- Hometown
  - Sappro, Hokkaido, Japan
- Affiliation
  - Hokkaido University

Snow Festival in Sapporo

- Field of Study
  - Selection of Substitute employees by management

Shift Management Tasks and Shift Schedule Modification

- **Selection of substitute employees by managers in shift-work workplaces**
  - Selection of employees to work in place of absentees (substitute employees)
  - Retention of initial number of employees scheduled to work
    - Existence of call centers with employees whose absenteeism rate exceeds 10%

Only for part-time employees, 20% of employees exceed 10%

- **Previous research approach**
  - **Shift rescheduling problem[1]**
    - Selection of substitute employees and regeneration of entire shift schedule
    - Effective in workplaces with complicated work constraints such as hospitals

Employees who do not violate work constraints by working in place of absentees

High workload for managers and employees

Pre-assign substitute attendance candidates and then select them

[1]Manabu Kitada, Kazuko Morizawa, Heuristic Method in Dynamic Nurse Scheduling Following a Sudden Absence of Nurses, J Jpn Manage Assoc 65, p.29-38(2014)

How to Select Substitute Employees

- Method of selecting substitutes from candidates

0-1 optimization problem

- Decision variable
  - Whether employees will work in place of absentees
- Objective function
  - Number of employees that could not be secured
- Constraints
  - Constraints of generation of shift schedule
  - Maximum limit of substitute attendance

- Necessary information
  - Absentees for the entire period
  - Employees available to work in place of absentees

Difficult to tabulate in advance

Request for substitute attendance by manager

- Request for candidates
  - Inquire whether candidates can work in place of absentees.
  - If substitute attendance is possible, request substitute attendance at that time.

- Necessary information
  - Absentees on that day
  - Candidate on that day

It is possible to pre-tabulate

Approach and Request Order Decision Strategies

- Approach of Our research
  - Request for substitute attendance by manager
    - Identification of candidates for substitute attendance in advance.
    - Determination of order of requests for candidates
    - Request according to determined order of requests
      - Request if substitute attendance is possible)
    - If it is possible, request substitute attendance at that time
      - (Non-)withdrawal of acceptance of the employee's request is not possible
    - Maximum acceptance count(maximum limit of substitute attendance) is set

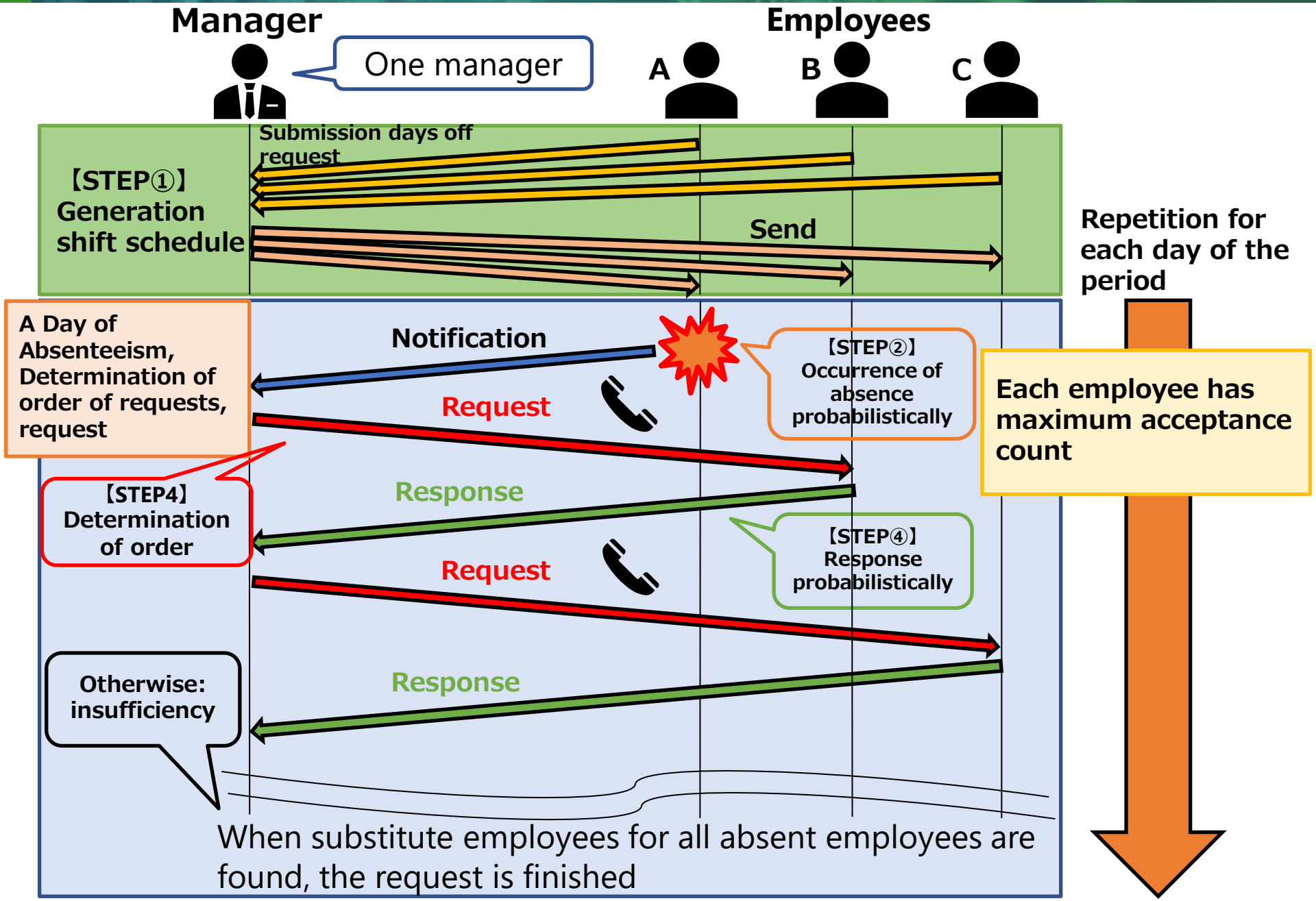
- Importance of order of requests

Compensation of absenteeism with a request order determination strategies constructed using observable information

Evaluation of request order determination strategies using observable information

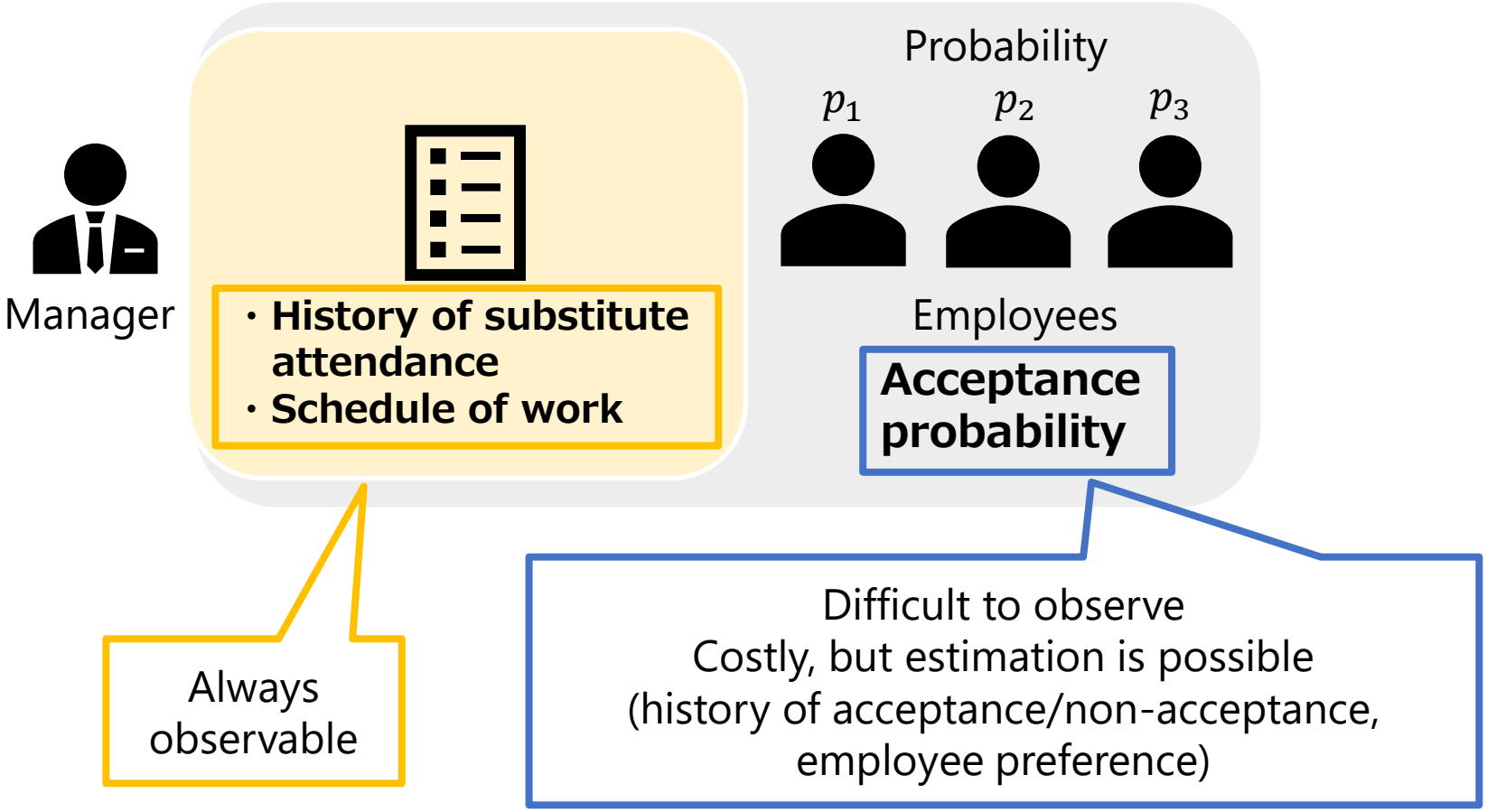
- Verification on simulation
  - Generation of shift schedule based on days off requests of employee
  - Probable absence from work on shift schedule
  - Request for substitute attendance for absenteeism (determination of order of requests → request)
- Evaluation metrics
  - **Insufficient number of employees**
    - Shortfall in number of employees after the request
  - Number of requests by manager

Overview of Simulation Model



Information used to determine the order of requests

- Available information is important in determining order of requests.



Strategy1

	Strategy	Expected Property	Reason
Strategy 1 Acceptance probability-base	(1-1) Descending order of acceptance probability	• Decrease in number of requests	Requested by employee with high acceptance probability
	(1-2) Ascending order of acceptance probability	• Decrease in insufficient number of employees • Increase in number of requests	Employees with high acceptance probability can work in place of the employee even in second half of period.

Strategy2

	Strategy	Expected Property	Reason
Strategy 2 History and work schedule-base	(2-1) Ascending order of number of previous substitute attendance	• Decrease in insufficient number of employees • increase in number of requests	Similar to ascending order of acceptance probability
	(2-2) Ascending order of number of days available for future	• Decrease in insufficient number of employees	Preservation of employees who can work many substitute attendance
	(2-3) Random	• Intermediate properties	

Necessity of absolute evaluation criteria

- Necessity of absolute evaluation criteria for proposed strategy in our research

- When absenteeism and available substitute employees are known for entire period, allocation of substitute employees
  (Absenteeism and available substitute employees-based approach)
  - 0-1 optimization problem
  - Difficult to execute in advance

Decision variable　Variables indicating substitute employees' substitution status
Objective function　Number of employees not secured
Constraints those of generation of shift schedule and maximum acceptance count

1. Absentees for entire period is determined in advance based on probability of absenteeism
2. Determine of substitute employees based on acceptance probability
3. Set constraints
4. Search for solutions by branch-and-bound method　(Solver : CPLEX)
5. In this research, average value of 10 seconds x 15 trials is obtained.
   - Exact solution is difficult to find in terms of computation time

Experimental Purpose

- Experiment 1
  - Verification of which strategy can reduce insufficient number of employees more effectively
- Experiment 2
  - Verification of whether there are sufficient cases where History and work schedule-base alone is effective
- Experiment 3
  - Investigation of relationship between insufficient number of employees and number of requests

Experiment Setup　Parameter sets

- Duration: 28 days (4 weeks), Employees : 50
- Preparation of parameter sets that are expected in a real workplace[2]
  - Employees with high(low) acceptance probability (high(low) acceptance level)

※ $p_{low} < p_{high}$

540 parameter sets

Parameter	Symbol	Min	Max	Increment	Iteration
Employee absenteeism rate per person	q	0.05	0.15	0.05	3
Max acceptance count	m	2	10	2	5
Acceptance probability of low acceptance level	p_{low}	0.05	0.20	0.05	4
Acceptance probability of high acceptance level	p_{high}	0.50	0.90	0.20	3
Number of employees with low acceptance level	n_{low}	35	45	5	3
Number of employees with high acceptance level	n_{high}	5	15	5	3

[2]Kohei Hatamoto, Soitiro Yokoyama, Tomohisa Yamashita, Hidenori Kawamura, Proposal of an Order Determination Algorithm for Substitute Attendance Requests, Journal of Information Processing Society of Japan, Vol.60 No.10 1757–1768(2019)

Experiment1

- Purpose
  - Verification of which strategy can reduce insufficient number of employees more effectively
- Verification method
  - 300 trials of simulation for entire period, and compare averages
    (same for Experiments 2 and 3)
  - Calculate number of parameter sets for which method was method with smallest insufficient number of employees for each request order decision strategy

Experiment1 Result

- In each strategy, number of parameter sets for which method was one resulting in smallest insufficient number of employees

	Number of parameter sets	Percentage	Number of parameter sets	Percentage
(1-1) Descending order of acceptance probability	1	0.18%		
(1-2) Ascending order of acceptance probability	470	87.03%		
(2-1) Ascending order of number of previous substitute attendance	5	0.92%	399	73.8%
(2-2) Ascending order of number of days available for future	46	8.51%	85	15.7%
(2-3)Random	18	3.33%	56	10.3%

Decrease in insufficient number of employees is achieved by having acceptance probability information in 87.03% of all parameter sets

Experiment1 Result

- In each strategy, number of parameter sets for which method was the one resulting in smallest insufficient number of employees

	Number of parameter sets	Percentage	Number of parameter sets	Percentage
(1-1) Descending order of acceptance probability	1	0.18%		
(1- **ac**		.03%		
(2- **nu** **su**		.92%	399	73.8%
(2- **for future**		.51%	85	15.7%
(2-3)Random	18	3.33%	56	10.3%

In history and work schedule-base, 2-1 ascending order of number of previous substitute attendance reduces number of employees in majority of parameter sets

Decrease in insufficient number of employees is achieved by having acceptance probability information in 87.03% of all parameter sets

Experiment2

- Purpose
  - Verification of whether there are sufficient cases where history and work schedule-base alone is effective
- Verification method
  - Compare difference between strategies that resulted in smallest insufficient number of employees in each of the groups

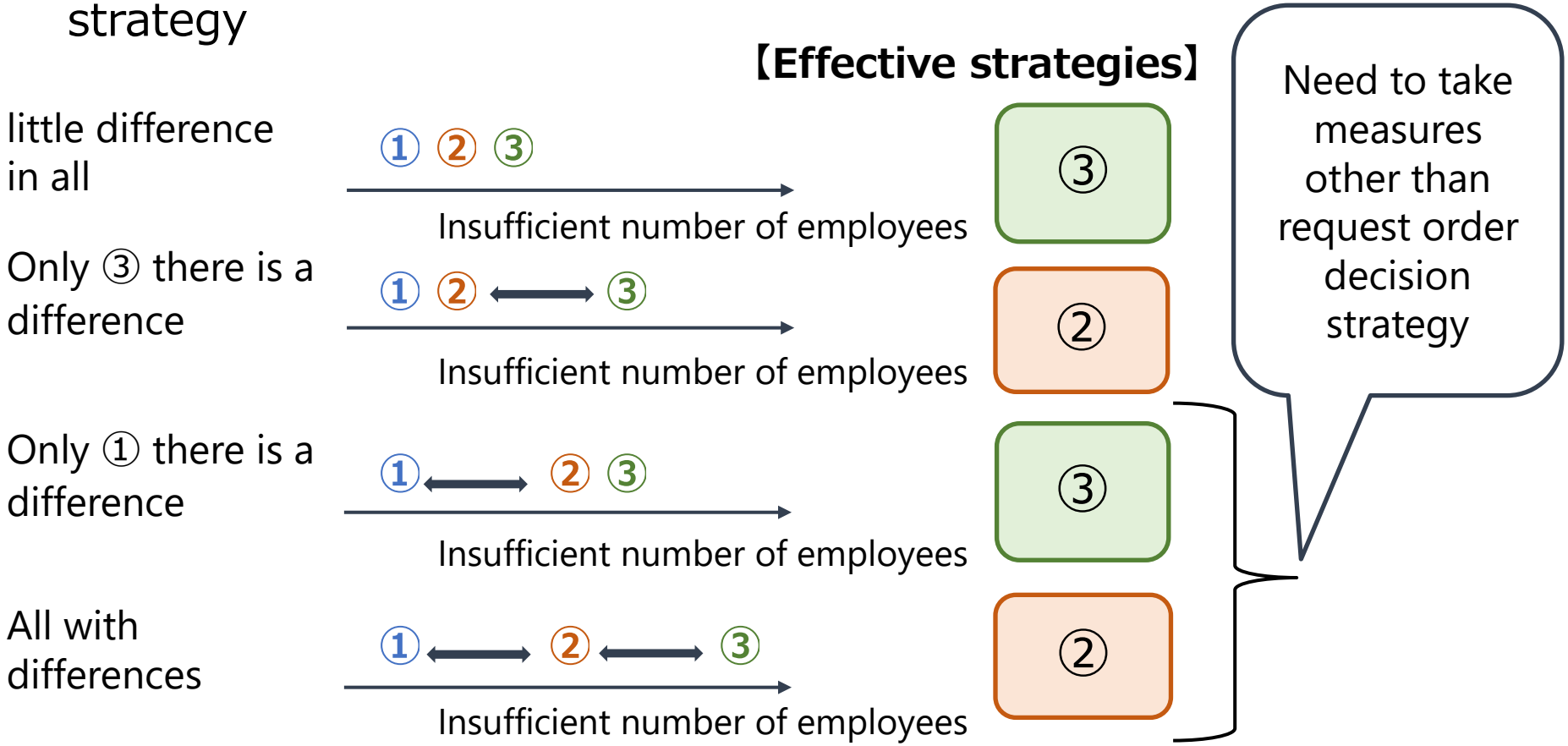
Experiment2

- Three categories of strategies

① Absenteeism and available substitute employees-base < ②Acceptance probability-base < ③ history and work schedule-base

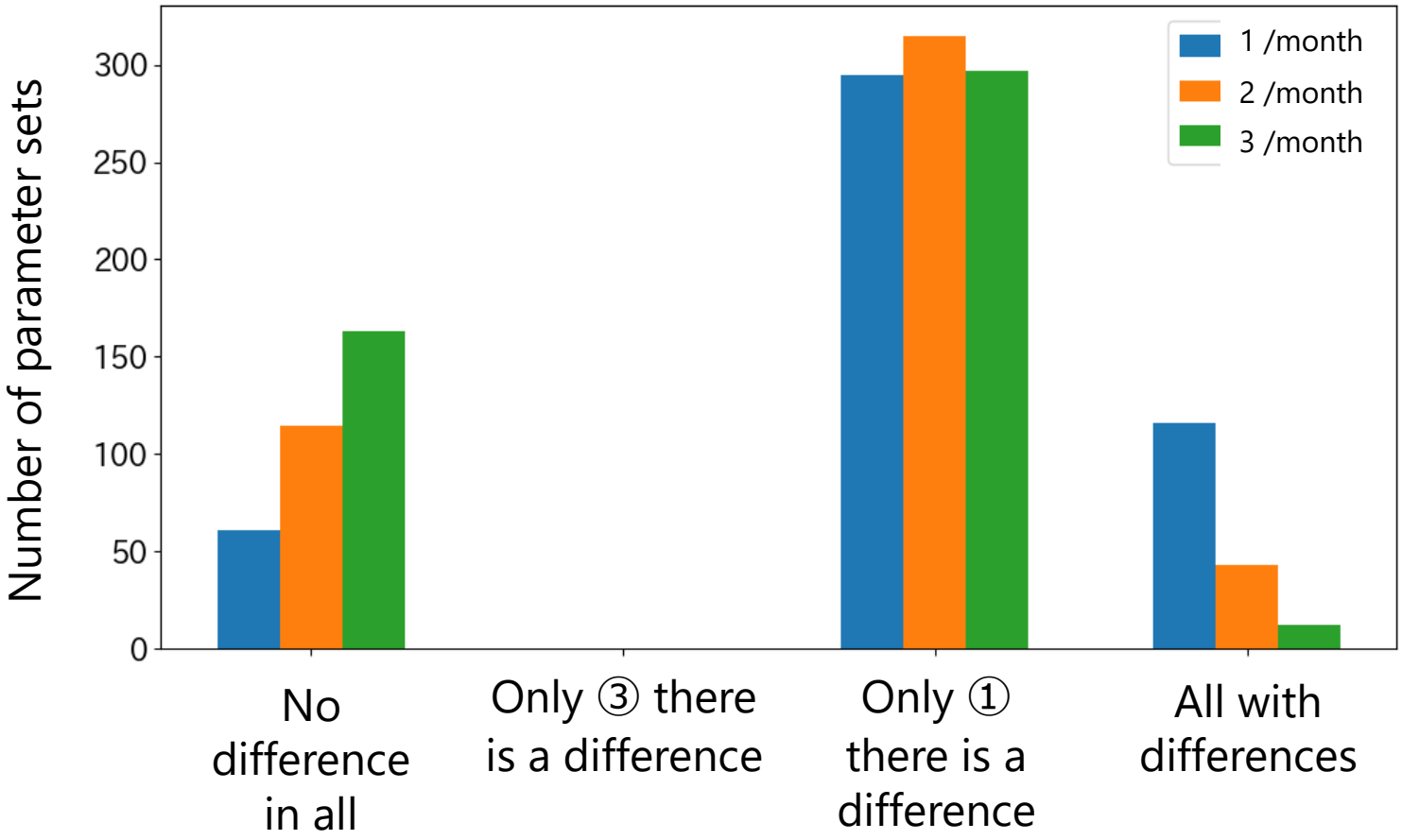
- Calculate number of parameter sets for four patterns based on difference in insufficient number of employees for each strategy

【Effective strategies】



Experiment2 Result

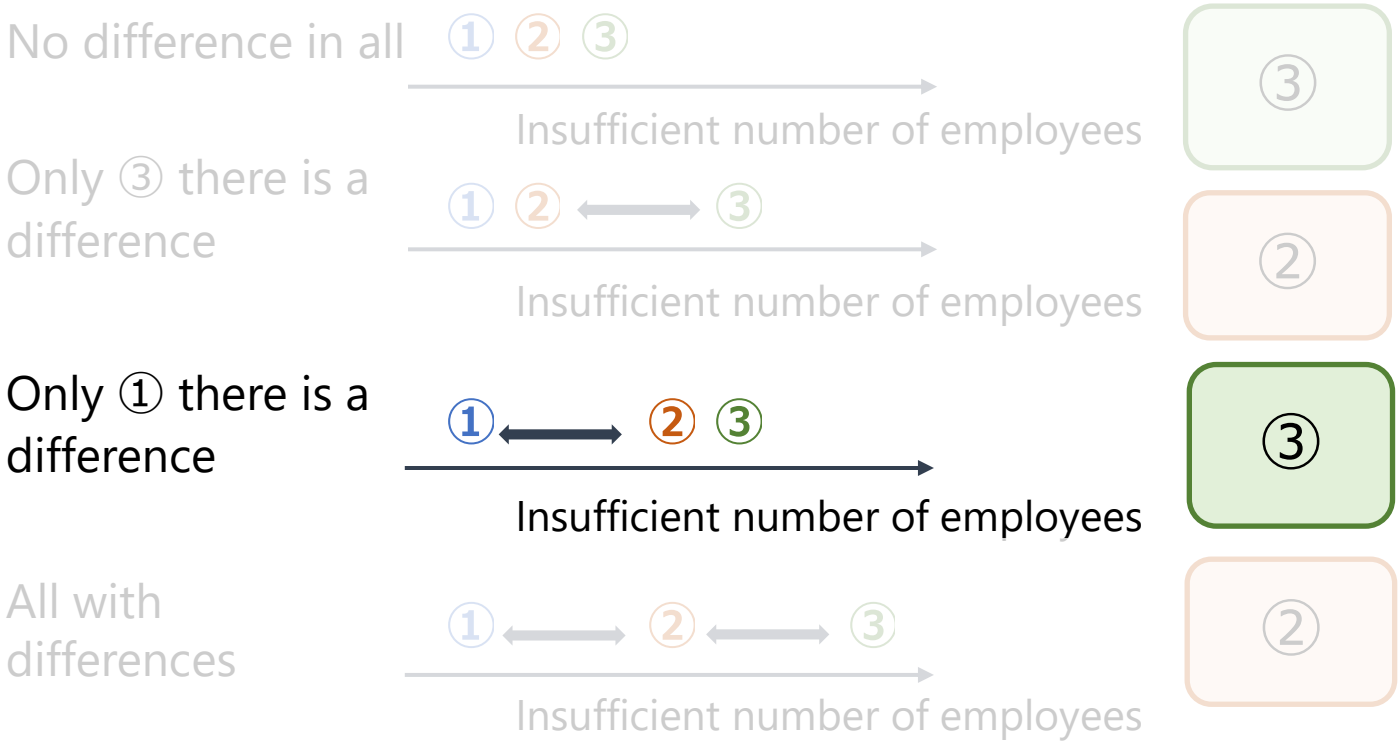
- Parameter sets that result in difference only on ①Absenteeism and available substitute employees-base is many



Experiment2 Result

- Parameter sets that result in difference only on ① Absenteeism and available substitute employees-base is many

- History and work schedule-base are often sufficient in many cases
  - No need to estimate acceptance probabilities at high cost



Experiment3

- Purpose
  - Investigation of relationship between insufficient number of employees and number of requests
- Verification method
  - Verification of changing from strategy with smallest insufficient number of employees to another strategy within each group of strategies
  - Measure number of parameter sets that cause difference in number of requests when strategy is changed
  - Comparison of relationship between number of requests and insufficient number of employees

Experiment3 Result

- Number of parameter sets where differences in number of requests from managers occurred

(Number of parameter sets where difference of three times per day occurs)

Difference in number of requests	Acceptance probability-base	History and work schedule-base
84 times or more per month	425	33
Less than 84 times per month	115	507

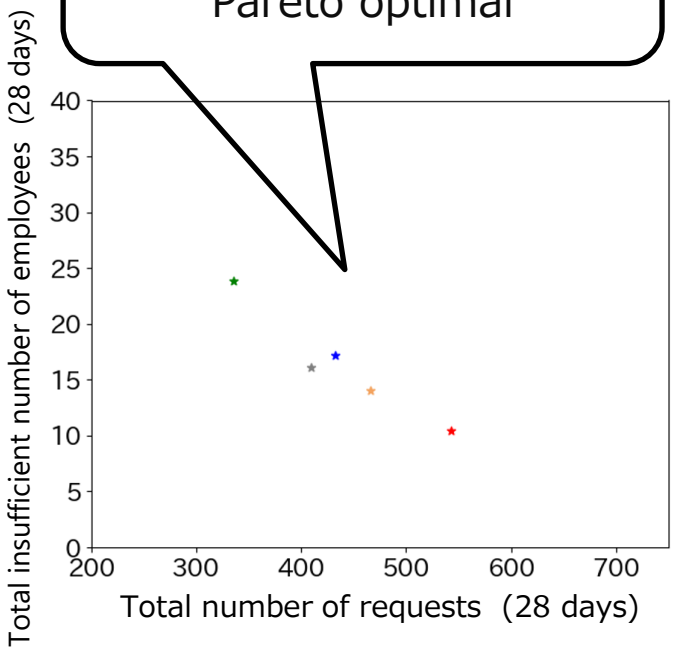
  - Acceptance probability-base have more parameters with larger differences in number of requests between strategies (78.7% of total)

  - Strategy 1-2 using information of acceptance probability: While insufficient number of employees was greatly reduced by using ascending order of acceptance probability, large increase in number of requests was observed

Experiment3 Result

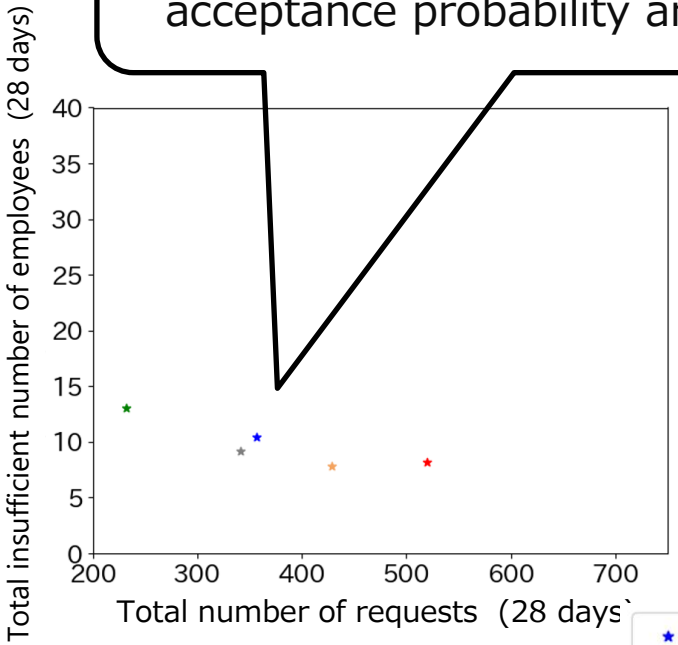
- **Relationship between insufficient number of employees and number of requests**
  - Plot parameter sets with differences in number of requests where difference in insufficient number of employees is largest within each strategy group

All strategies except for (2-3) random request are Pareto optimal

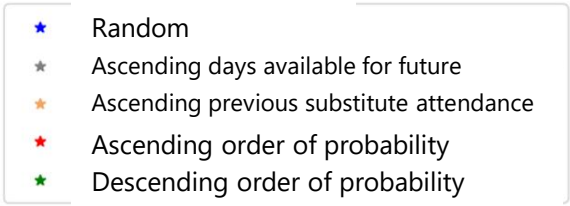


Most insufficient number of employees differences between strategies acceptance probability base

All strategies except for (2-3) random request and (1-2) ascending order of acceptance probability are Pareto optimal



Most insufficient number of employees between strategies history and work schedule base



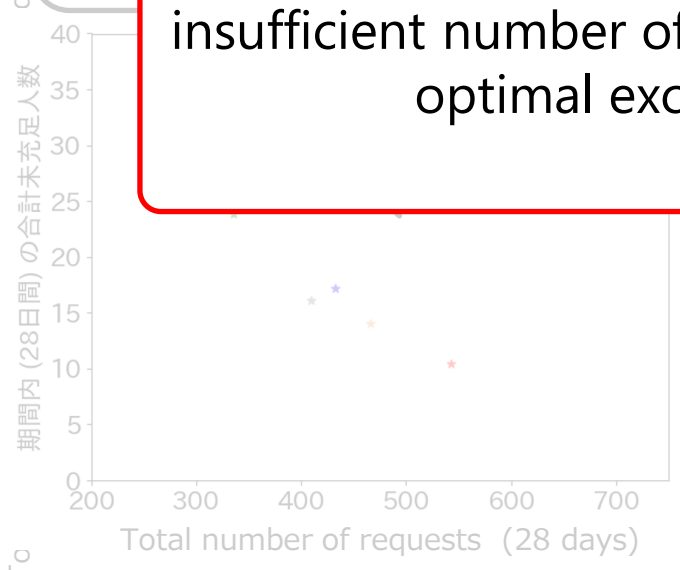
Experiment3 Result

- **Relationship between insufficient number of employees and number of requests**
  - Plot parameter sets with differences in number of requests where difference in insufficient number of employees is largest within each strategy group

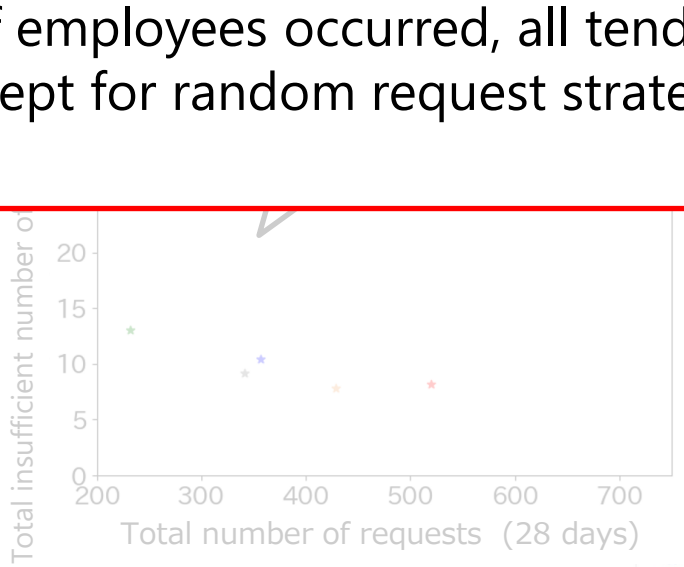
All strategies except for (2-3)

All strategies except for (2-3) random

For the top 2 to 5 positions where largest differences in insufficient number of employees occurred, all tend to be Pareto optimal except for random request strategy



Most insufficient number of employees differences between strategies acceptance probability base



Most insufficient number of employees between strategies history and work schedule base

Experiment3 Result

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Possible to reduce number of requests by about 200 times/month by using (1-1) descending order of acceptance probability

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Possible to reduce insufficient number of employees by about 10 employees/month by using (1-2) ascending order of acceptance probability

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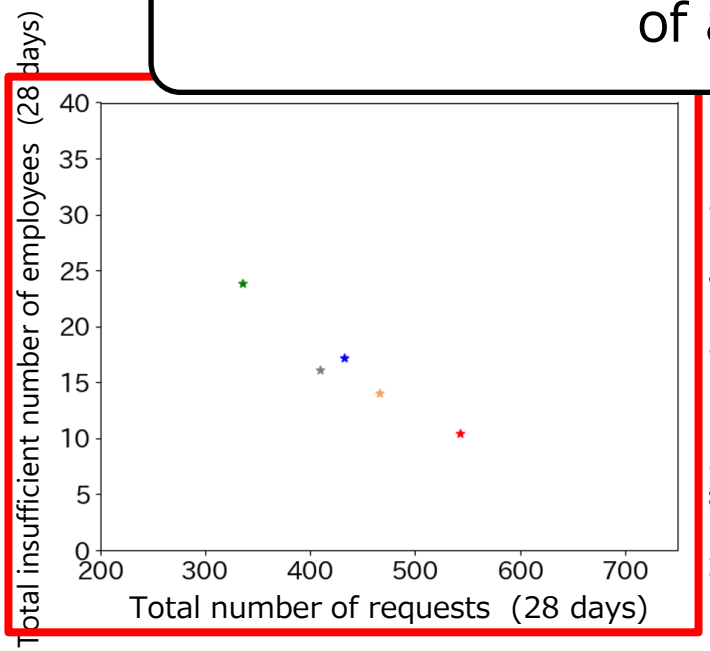
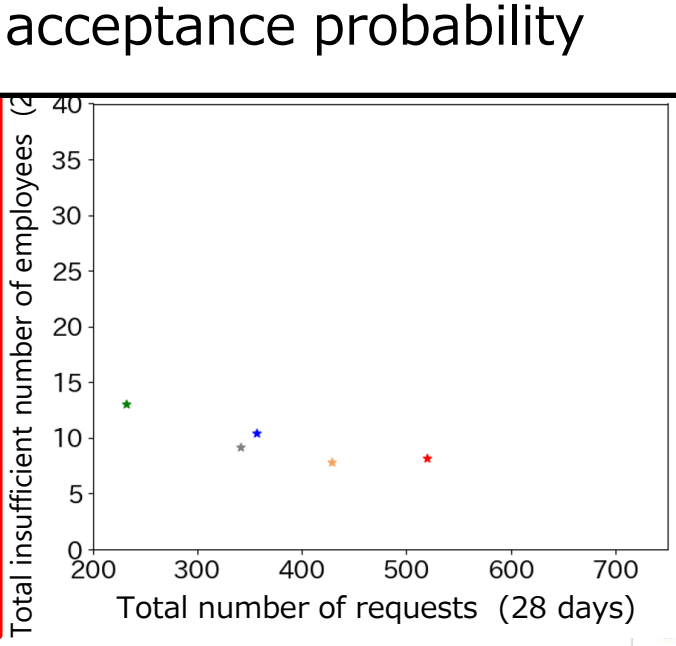
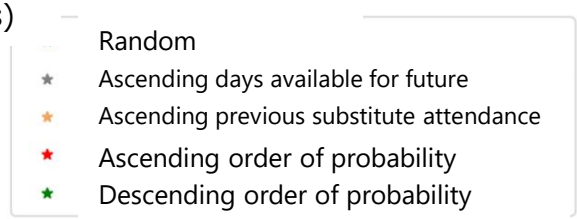


Most insufficient number of employees differences between strategies acceptance probability base



Most insufficient number of employees between strategies history and work schedule base



Experiment3 Result

- Possible to reduce number of requests by about 100 times/month by using (2-2) ascending order of number of days available for future

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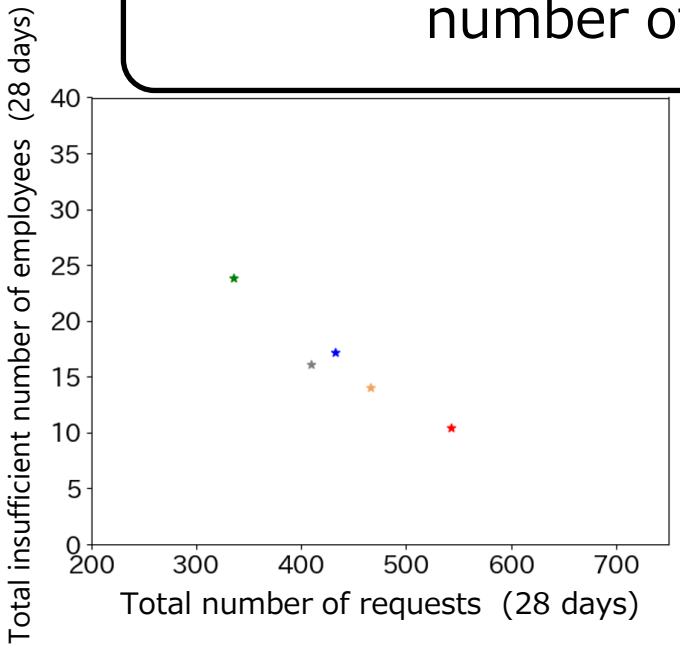
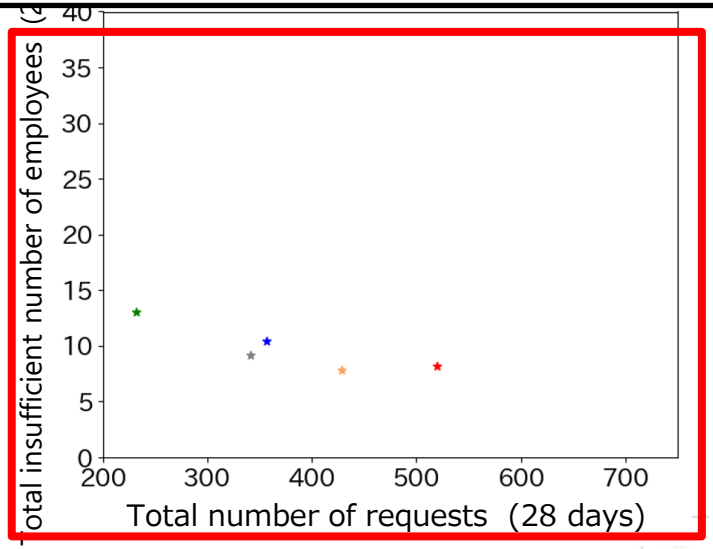
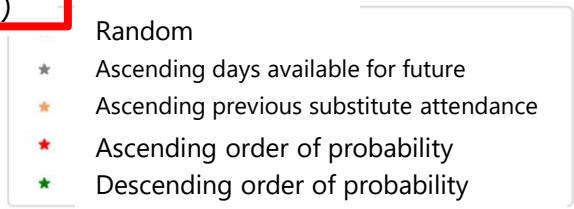
Possible to reduce insufficient number of employees by about 2 employees/month by using (2-1) ascending order of number of previous substitute attendance



Most insufficient number of employees differences between strategies acceptance probability-base



Most insufficient number of employees between strategies history and work schedule-base



Conclusion of experiment

- In many cases, acceptance probability-base have smaller insufficient number of employees than history and work schedule-base

- In many cases, value of insufficient number of employees between acceptance probability-based and history and work schedule-base was small

it was sufficient to use history and work schedule-base rather than costly acceptance probability-base

- Focusing on set of parameters that differed in number of requests, trade-off was made between insufficient number of employees and number of requests

Conclusion

- Build an substitute attendance request simulator
- Verification of request strategy based on following information
  - Acceptance probability-base
  - History and work schedule-base
  - Absenteeism and available substitute employees-base
- Future Outlook
  - Development of request strategy that takes into account following indicators
    - Bias in number of employees' substitute attendance
    - Bias in number of requests received by employees