МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ

ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ БЮДЖЕТНОЕ
ОБРАЗОВАТЕЛЬНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ОБРАЗОВАНИЯ

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Лабораторная работа №4

по дисциплине: «Исследование операций»

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Закрытая транспортная задача

Вариант 8

Цель работы: изучить математическую модель транспортной задачи, овладеть методами решения этой задачи.

Ход работы

$$\vec{a} = (21, 22, 22, 20);$$

$$\vec{b} = (18, 20, 19, 19, 9);$$

$$C = \begin{pmatrix} 14 & 27 & 6 & 16 & 8 \\ 2 & 4 & 19 & 4 & 27 \\ 26 & 23 & 1 & 20 & 3 \\ 24 & 5 & 12 & 30 & 5 \end{pmatrix}$$

1. Изучить содержательную и математическую постановки закрытой транспортной задачи, методы нахождения первого опорного решения ее системы ограничений. Изучить понятие цикла пересчета в матрице перевозок. Овладеть распределительным методом и методом потенциалов, а также их алгоритмами.

2. Составить и отладить программы решения транспортной задачи распределительным методом и методом потенциалов.

   Написанная библиотека:

```
#include "transport.h"
#include <utility>

TransportTable::TransportTable(Matrix costMatrix, vector<float> stock,
                               vector<float> requests) {
    this->costMatrix = costMatrix;
    this->stock = std::move(stock);
    this->requests = std::move(requests);

    planTable = vector<vector<PlanTableElement >>();
    for (int row = 0; row < costMatrix.getRows(); row++) {
        planTable.emplace_back(costMatrix.getColumns());
        for (int column = 0; column < costMatrix.getColumns(); column++) {
            planTable[row][column].isBasic = false;
            planTable[row][column].value = 0;
        }
    }
}

void TransportTable::fillTransportTableMinValue() {
    for (int row = 0; row < planTable.size(); row++) {
        for (int column = 0; column < planTable[0].size(); column++) {
            planTable[row][column].isBasic = true;
        }
    }

    vector<float> stockTmp = stock;
    vector<float> requestsTmp = requests;

    bool isFull = false;
    while (!isFull) {
        Position minValuePosition = findMinValuePosition();

        if (fcmp(requestsTmp[minValuePosition.column],
                 stockTmp[minValuePosition.row])) {
            planTable[minValuePosition.row][minValuePosition.column].value =
requestsTmp[minValuePosition.column];
            requestsTmp[minValuePosition.column] = 0;
            stockTmp[minValuePosition.row] = 0;

            for (int row = 0; row < planTable.size(); row++) {
                if (row != minValuePosition.row &&
planTable[row][minValuePosition.column].value == 0) {
                    planTable[row][minValuePosition.column].isBasic = false;
                }
            }

            for (int column = 0; column < planTable.size(); column++) {
                if (column != minValuePosition.column &&
planTable[minValuePosition.row][column].value == 0) {
                    planTable[minValuePosition.row][column].isBasic = false;
                }
            }
        } else if (requestsTmp[minValuePosition.column] <
stockTmp[minValuePosition.row]) {
            planTable[minValuePosition.row][minValuePosition.column].value =
requestsTmp[minValuePosition.column];
            stockTmp[minValuePosition.row] -= requestsTmp[minValuePosition.column];
            requestsTmp[minValuePosition.column] = 0;

            for (int row = 0; row < planTable.size(); row++) {
                if (row != minValuePosition.row &&
planTable[row][minValuePosition.column].value == 0) {
                    planTable[row][minValuePosition.column].isBasic = false;
                }
            }
        } else {
            planTable[minValuePosition.row][minValuePosition.column].value =
stockTmp[minValuePosition.row];
            requestsTmp[minValuePosition.column] -= stockTmp[minValuePosition.row];
            stockTmp[minValuePosition.row] = 0;

            for (int column = 0; column < planTable.size(); column++) {
                if (column != minValuePosition.column &&
planTable[minValuePosition.row][column].value
                                                         == 0) {
                    planTable[minValuePosition.row][column].isBasic = false;
                }
            }
        }

        isFull = checkIfTableIsFull();
    }
}

bool TransportTable::checkIfTableIsFull() {
    for (int row = 0; row < planTable.size(); row++) {
        for (int column = 0; column < planTable[0].size(); column++) {
            if (planTable[row][column].isBasic &&
fcmp(planTable[row][column].value, 0))
                return false;
        }
    }

    return true;
}

Position TransportTable::findMinValuePosition() {
    Position minValuePosition(0, 0);
    float minValue = INT32_MAX;

    for (int row = 0; row < planTable.size(); row++) {
        for (int column = 0; column < planTable[0].size(); column++) {
            if (planTable[row][column].isBasic &&
fcmp(planTable[row][column].value, 0)
                && costMatrix.getData(row, column) < minValue) {
                minValuePosition = Position(row, column);
                minValue = costMatrix.getData(row, column);
            }
        }
    }

    return minValuePosition;
}

float TransportTable::countCycleGamma(Sequence cycle) {
    float sum = 0;

    for (int i = 0; i < cycle.positions.size() - 1; i++) {
        float nextValue = costMatrix.getData(cycle.positions[i].row,
cycle.positions[i].column);
        if (i % 2 == 0) {
            sum += nextValue;
        } else {
            sum -= nextValue;
        }
    }

    return sum;
}

Sequence TransportTable::findCycle(Position start) {
    Sequence sequence;
    sequence.positions.push_back(start);
    return _findCycle(sequence, Direction::Any);
}

Sequence TransportTable::_findCycle(Sequence sequence, Direction direction) {
    if (sequence.checkIfCycle()) {
        return sequence;
    } else {
        Position currentPosition = sequence.getPosition(-1);

        if (direction == Direction::Vertical || direction == Direction::Any) {
            //Проход вверх
      while (currentPosition.row >= 0) {
                bool isCurrentPositionInSequence =
sequence.checkIfPositionInSequence(currentPosition);

                if (getPlanTableElement(currentPosition).isBasic &&
!isCurrentPositionInSequence ||
                    sequence.positions.size() > 2 && currentPosition ==
sequence.positions[0]) {
                    Sequence newSequence = sequence;
                    newSequence.positions.push_back(currentPosition);

                    Sequence resultSequence = _findCycle(newSequence,
Direction::Horizontal);
                    if (!resultSequence.isEmpty()) {
                        return resultSequence;
                    }
                }

                currentPosition.row--;
            }

            //Проход вниз
      currentPosition = sequence.getPosition(-1);

            while (currentPosition.row <= planTable.size() - 1) {
                bool isCurrentPositionInSequence =
sequence.checkIfPositionInSequence(currentPosition);

                if (getPlanTableElement(currentPosition).isBasic &&
!isCurrentPositionInSequence ||
                    sequence.positions.size() > 2 && currentPosition ==
sequence.positions[0]) {
                    Sequence newSequence = sequence;
                    newSequence.positions.push_back(currentPosition);

                    Sequence resultSequence = _findCycle(newSequence,
Direction::Horizontal);
                    if (!resultSequence.isEmpty()) {
                        return resultSequence;
                    }
                }

                currentPosition.row++;
            }
        }

        if (direction == Direction::Horizontal || direction == Direction::Any) {
            //Проход влево
      currentPosition = sequence.getPosition(-1);
```

```
            while (currentPosition.column >= 0) {
                bool isCurrentPositionInSequence =
sequence.checkIfPositionInSequence(currentPosition);

                if (getPlanTableElement(currentPosition).isBasic &&
!isCurrentPositionInSequence ||
                    sequence.positions.size() > 2 && currentPosition ==
sequence.positions[0]) {
                    Sequence newSequence = sequence;
                    newSequence.positions.push_back(currentPosition);

                    Sequence resultSequence = _findCycle(newSequence,
Direction::Vertical);
                    if (!resultSequence.isEmpty()) {
                        return resultSequence;
                    }
                }

                currentPosition.column--;
            }


            //Проход вправо
      currentPosition = sequence.getPosition(-1);

            while (currentPosition.column <= planTable[0].size() - 1) {
                currentPosition.column++;

                bool isCurrentPositionInSequence =
sequence.checkIfPositionInSequence(currentPosition);

                if (getPlanTableElement(currentPosition).isBasic &&
!isCurrentPositionInSequence ||
                    sequence.positions.size() > 2 && currentPosition ==
sequence.positions[0]) {
                    Sequence newSequence = sequence;
                    newSequence.positions.push_back(currentPosition);

                    Sequence resultSequence = _findCycle(newSequence,
Direction::Vertical);
                    if (!resultSequence.isEmpty()) {
                        return resultSequence;
                    }
                }
            }
        }

        return {};
    }
}

PlanTableElement TransportTable::getPlanTableElement(Position position) {
    return planTable[position.row][position.column];
}

void TransportTable::makeShiftByCycle(Sequence cycle, float value) {
    for (int i = 0; i < cycle.positions.size() - 1; i++) {
        Position currentPosition = cycle.getPosition(i);
        if (i % 2 == 0) {
            planTable[currentPosition.row][currentPosition.column].value += value;
        } else {
            planTable[currentPosition.row][currentPosition.column].value -= value;
        }
    }
}



bool Sequence::checkIfCycle() {
    for (int i = 0; i < positions.size() - 1; i++) {
        if (positions[i].row != positions[i + 1].row &&
            positions[i].column != positions[i + 1].column) {
            return false;
        }
    }

    return positions.size() > 1 && positions[0] == positions[positions.size() - 1];
}

void Sequence::addPosition(Position position) {
    positions.push_back(position);
}

Position Sequence::getPosition(int index) {
    if (index >= 0)
        return positions[index];
    else {
        return positions[positions.size() + index];
    }
}

bool Sequence::isEmpty() {
    return positions.empty();
}

bool Sequence::checkIfPositionInSequence(Position target) {
    for (int i = 0; i < positions.size(); i++) {
        if (positions[i] == target)
            return true;
    }

    return false;
}

bool Position::operator==(Position other) {
    return this->row == other.row && this->column == other.column;
}
```

Основной код распределительного метода:

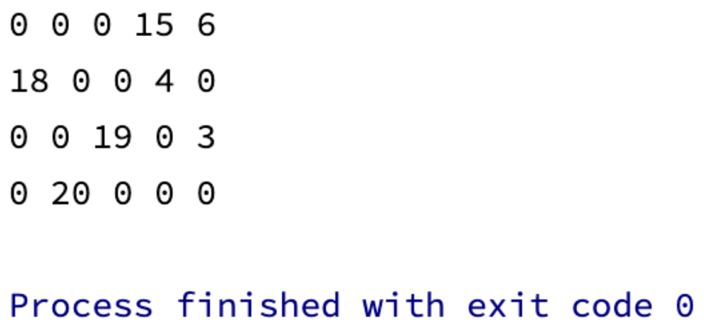
```
void TransportTable::solveByDistributiveMethod() {
    fillTransportTableMinValue();

    bool foundSolution = false;
    while (!foundSolution) {
        float minGamma = INT32_MAX;
        Sequence cycleWithMinValue;

        for (int i = 0; i < planTable.size(); i++) {
            for (int j = 0; j < planTable[0].size(); j++) {
                std::cout << planTable[i][j].value << " ";
            }

            std::cout << "\n";
        }

        std::cout << "\n";

        for (int row = 0; row < planTable.size(); row++) {
            for (int column = 0; column < planTable[0].size(); column++) {
                if (!planTable[row][column].isBasic) {
                    Sequence currentCycle = findCycle({row, column});
                    float cycleGamma = countCycleGamma(currentCycle);

                    if (cycleGamma < minGamma) {
                        minGamma = cycleGamma;
                        cycleWithMinValue = currentCycle;
                    }
                }
            }
        }

        if (minGamma < 0 && !fcmp(minGamma, 0)) {
            float minAmongNegative = INT32_MAX;
            Position positionOfMinAmongNegative{-1, -1};

            for (int i = 1; i < cycleWithMinValue.positions.size() - 1; i += 2) {
                float currentValueWithNegativePosition =
getPlanTableElement(cycleWithMinValue.getPosition(i)).value;
                if (currentValueWithNegativePosition < minAmongNegative) {
                    minAmongNegative = currentValueWithNegativePosition;
                    positionOfMinAmongNegative = cycleWithMinValue.getPosition(i);
                }
            }

            makeShiftByCycle(cycleWithMinValue, minAmongNegative);

planTable[positionOfMinAmongNegative.row][positionOfMinAmongNegative.column].isBasi
c = false;

planTable[cycleWithMinValue.getPosition(0).row][cycleWithMinValue.getPosition(0).co
lumn].isBasic = true;
        } else {
            foundSolution = true;
        }
    }
}

void TransportTable::fillPotentialsColumn(vector<Potential> &rows,
vector<Potential> &columns, int column) {
    for (int row = 0; row < rows.size(); row++) {
        if (planTable[row][column].isBasic && !rows[row].isSet) {
            rows[row].value = costMatrix.getData(row, column) -
columns[column].value;
            rows[row].isSet = true;
            fillPotentialsRow(rows, columns, row);
        }
    }
```

```
}

void TransportTable::fillPotentialsRow(vector<Potential> &rows, vector<Potential>
&columns, int row) {
    for (int column = 0; column < columns.size(); column++) {
        if (planTable[row][column].isBasic && !columns[column].isSet) {
            columns[column].value = costMatrix.getData(row, column) -
rows[row].value;
            columns[column].isSet = true;
            fillPotentialsColumn(rows, columns, column);
        }
    }
}
```

main.cpp

```
#include <iostream>
#include "libs/matrix/matrix.h"
#include "libs/transport/transport.h"

int main() {
    Matrix costMatrix;
    costMatrix.inputMatrix(4, 5, {
            {14, 27, 6,  16, 8},
            {2,  4,  19, 4,  27},
            {26, 23, 1,  20, 3},
            {24, 5,  12, 30, 5}
    });

    vector<float> stock{21, 22, 22, 20};
    vector<float> requests{18, 20, 19, 19, 9};

    TransportTable transportTable(costMatrix, stock, requests);

    transportTable.solveByDistributiveMethod();

    for (int i = 0; i < transportTable.planTable.size(); i++) {
        for (int j = 0; j < transportTable.planTable[0].size(); j++) {
            std::cout << transportTable.planTable[i][j].value << " ";
        }

        std::cout << "\n";
    }
}
```

Пример вывода программы:



```
0 0 0 15 6
18 0 0 4 0
0 0 19 0 3
0 20 0 0 0


Process finished with exit code 0
```

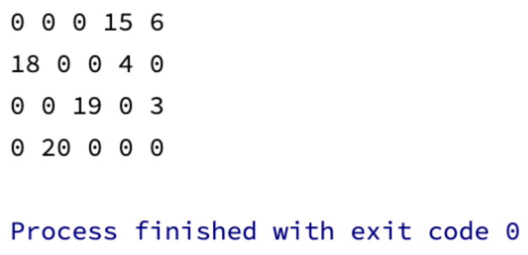
Основной код метода потенциалов:

```
void TransportTable::solveByPotentialMethod() {
    fillTransportTableMinValue();

    bool foundSolution = false;

    while (!foundSolution) {
        vector<Potential> stockPotentials(stock.size());
        vector<Potential> requestPotentials(requests.size());

        for (auto potential: stockPotentials) {
            potential.isSet = false;
        }

        for (auto potential: requestPotentials) {
            potential.isSet = false;
        }

        requestPotentials[0].value = 0;
        requestPotentials[0].isSet = true;
        fillPotentialsColumn(stockPotentials, requestPotentials, 0);

        float minPotentialValue = INT32_MAX;
        Position minPotentialPosition{-1, -1};
        for (int row = 0; row < costMatrix.getRows(); row++) {
            for (int column = 0; column < costMatrix.getColumns(); column++) {
                float currentPotential = costMatrix.getData(row, column) -
(stockPotentials[row].value +

requestPotentials[column].value);
                if (currentPotential < minPotentialValue) {
                    minPotentialValue = currentPotential;
                    minPotentialPosition = Position {row, column};
                }
            }
        }

        if (minPotentialValue < 0 && !fcmp(minPotentialValue, 0)) {
            Sequence cycleWithMinValue = findCycle(minPotentialPosition);

            float minAmongNegative = INT32_MAX;
            Position positionOfMinAmongNegative{-1, -1};

            for (int i = 1; i < cycleWithMinValue.positions.size() - 1; i += 2) {
                float currentValueWithNegativePosition =
getPlanTableElement(cycleWithMinValue.getPosition(i)).value;
                if (currentValueWithNegativePosition < minAmongNegative) {
                    minAmongNegative = currentValueWithNegativePosition;
                    positionOfMinAmongNegative = cycleWithMinValue.getPosition(i);
                }
            }

            makeShiftByCycle(cycleWithMinValue, minAmongNegative);

planTable[positionOfMinAmongNegative.row][positionOfMinAmongNegative.column].isBasi
c = false;

planTable[cycleWithMinValue.getPosition(0).row][cycleWithMinValue.getPosition(0).co
lumn].isBasic = true;
        } else {
            foundSolution = true;
        }
    }
}
```

main.cpp

```cpp
#include <iostream>
#include "libs/matrix/matrix.h"
#include "libs/transport/transport.h"

int main() {
    Matrix costMatrix;
    costMatrix.inputMatrix(4, 5, {
            {14, 27, 6,  16, 8},
            {2,  4,  19, 4,  27},
            {26, 23, 1,  20, 3},
            {24, 5,  12, 30, 5}
    });

    vector<float> stock{21, 22, 22, 20};
    vector<float> requests{18, 20, 19, 19, 9};

    TransportTable transportTable(costMatrix, stock, requests);

    transportTable.solveByPotentialMethod();

    for (int i = 0; i < transportTable.planTable.size(); i++) {
        for (int j = 0; j < transportTable.planTable[0].size(); j++) {
            std::cout << transportTable.planTable[i][j].value << " ";
        }

        std::cout << "\n";
    }
}
```

Пример вывода программы:



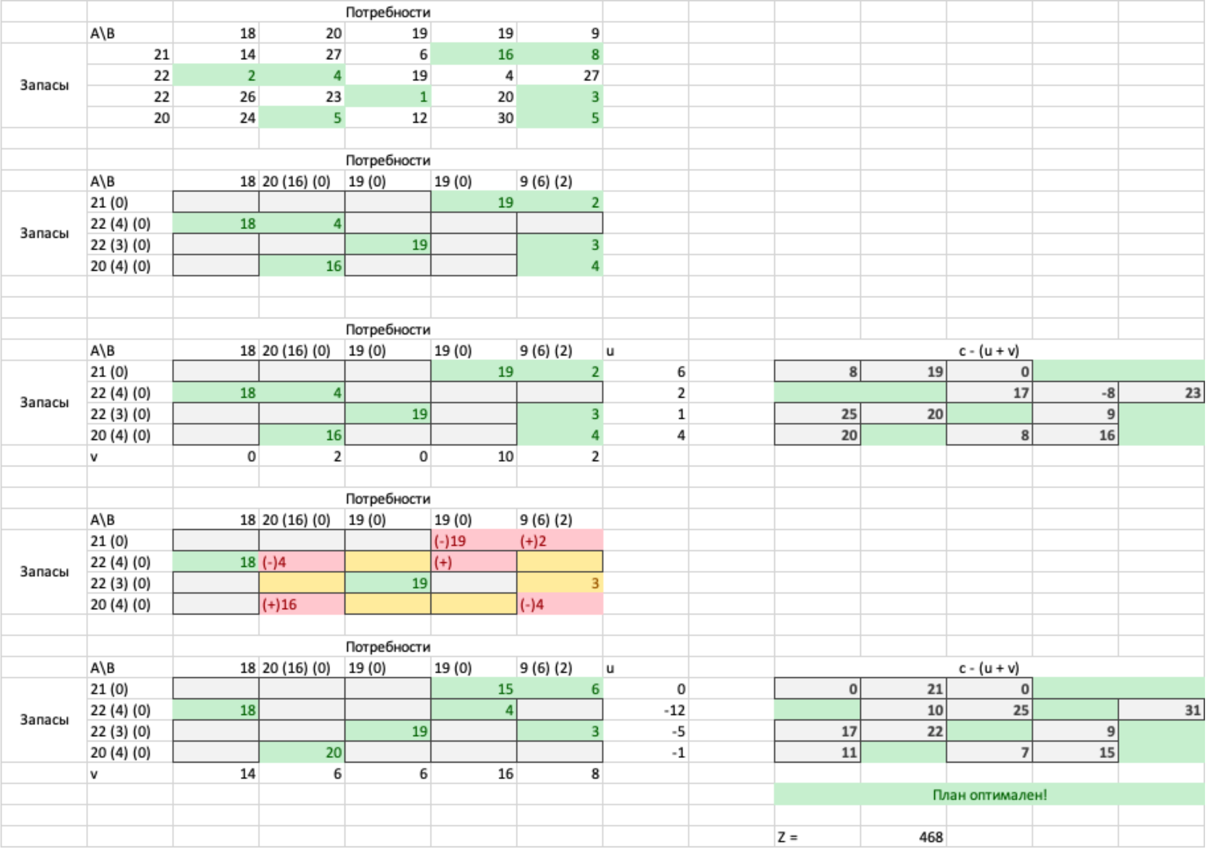
```
0 0 0 15 6
18 0 0 4 0
0 0 19 0 3
0 20 0 0 0

Process finished with exit code 0
```

3. Для подготовки тестовых данных решить вручную одну из следующих ниже задач.

$$\vec{a} = (21,\ 22,\ 22,\ 20);$$

$$\vec{b} = (18,\ 20,\ 19,\ 19,\ 9);$$

$$C = \begin{pmatrix} 14 & 27 & 6 & 16 & 8 \\ 2 & 4 & 19 & 4 & 27 \\ 26 & 23 & 1 & 20 & 3 \\ 24 & 5 & 12 & 30 & 5 \end{pmatrix}$$



		Потребности				
	A\B	18	20	19	19	9
Запасы	21	14	27	6	16	8
	22	2	4	19	4	27
	22	26	23	1	20	3
	20	24	5	12	30	5

		Потребности				
	A\B	18	20 (16) (0)	19 (0)	19 (0)	9 (6) (2)
Запасы	21 (0)				19	2
	22 (4) (0)	18	4			
	22 (3) (0)			19		3
	20 (4) (0)		16			4

		Потребности					
	A\B	18	20 (16) (0)	19 (0)	19 (0)	9 (6) (2)	u
Запасы	21 (0)				19	2	6
	22 (4) (0)	18	4				2
	22 (3) (0)			19		3	1
	20 (4) (0)		16			4	4
	v	0	2	0	10	2	

c - (u + v)				
8	19	0		
		17	-8	23
25	20		9	
20		8	16	

		Потребности				
	A\B	18	20 (16) (0)	19 (0)	19 (0)	9 (6) (2)
Запасы	21 (0)				(-)19	(+)2
	22 (4) (0)	18	(-)4		(+)	
	22 (3) (0)			19		3
	20 (4) (0)		(+)16			(-)4

		Потребности					
	A\B	18	20 (16) (0)	19 (0)	19 (0)	9 (6) (2)	u
Запасы	21 (0)				15	6	0
	22 (4) (0)	18			4		-12
	22 (3) (0)			19		3	-5
	20 (4) (0)		20				-1
	v	14	6	6	16	8	

c - (u + v)				
0	21	0		
	10	25		31
17	22		9	
11		7	15	

План оптимален!

Z = 468

Вывод: в ходе лабораторной работы мы изучили методы решения закрытой транспортной задачи; реализовали заполнение исходной таблицы методом наименьшей стоимости, решение задачи методом потенциалов и распределительным методом.