Aalto University

Mat-2.4177 Seminar on Case Studies in Operation Research
Intermediate report

Modeling Logistics Network In a Crisis Situation

Client: Defence Forces Technical Research Centre

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Introduction

After the submission of the project plan document around a month ago our research team has started working hard on mathematical defining of the logistics network model. As soon as the team has succeeded defining parameters and mathematical concepts of the model satisfactorily, it is time to start implementing the modeling software. Programming will be anything but a trivial exercise when considering the lack of programming experience among the team members.

Only minor changes in the scope

The purpose of this study is to design and implement a simulation software which facilitates decision making process when planning logistics to a region under a crisis.

The software simulates the logistic network in a catastrophe area, where resources are extremely limited, roads and facilities might be damaged and the need for aid is immediate. The software provides a solution how to distribute necessary supplies to distressed people in the crisis region in an effective manner.

The scope of the study has remained almost the same as planned at the outset of the project. Nevertheless, in agreement with the client the focus of the study has been shifted slightly from programming a software towards mathematical and conceptual definition of the logistics network. "Think big, demonstrate in short" was the message from the client.

Recent advancement – new challenges have emerged

Over the first two months of the project, the research team has spent mainly on defining concepts and parameters of a logistics network in the crisis region. The main problem has been divided into four sub-problems, each of them having own characteristics in the mathematical sense.

1) What triggers the demand for resupply from the nodes (batch size and service level problem)

2) How are the orders distributed to hubs (scheduling problem),

3) How does the transportation vehicle choose which way it's going to drive there (routing problem)

4) How to model the delay and changes in the route network.

Annex A, in the end of the report, introduces the four problems in detail and provides preliminary solutions for the sub-problems.

Schedule holds

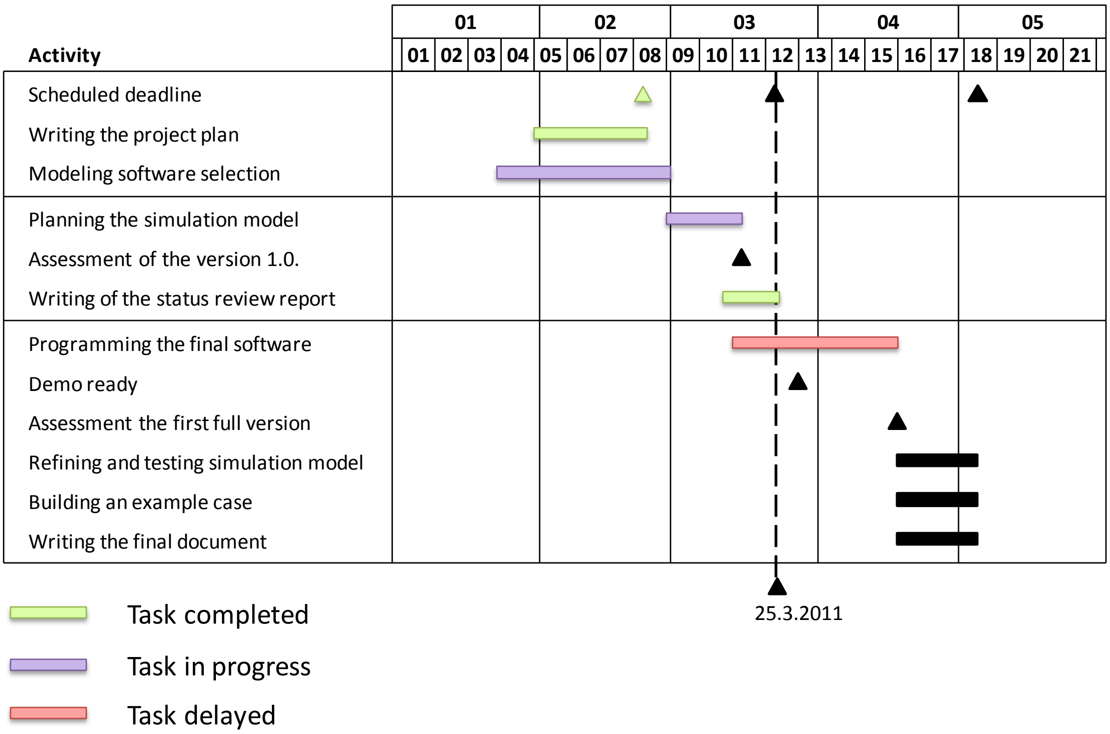
Initial tasks have not been changed but some minor adjustments for the original job allocation has been done. Because tasks 1 and 2 have already been completed, actual time spent on these tasks have been revised. The first two tasks have not required as much labor as the research team had anticipated in the beginning. On the other hand, the task 4 "planning the simulation model" will consume roughly 25 hours more than planned initially. The total amount of work seems to remain slightly under 450 hours.

Table 1: Key tasks and their description

Task	**Description**	**Labor allocation Actual /** projected	**Status**
T1 Kick-off meeting between the client and the project team	Definition of objectives, scope, methods and schedule of the project	**10** / 20	Completed
T2 Writing of the project plan	Documentation of the issues discussed and decided in the kick-off meeting	**30** / 40	Completed
T3 Selection of the modeling software	Determination of criteria of the modeling software, short listing of potential alternatives. Selection of the software.	25	MatLab is the strongest candidate (90%)
T4 Planning the simulation model	Creating a detailed blueprint of the model defining necessary boundary conditions and choosing the target of analysis	100	In progress (50 %)
T5 Assessment of the version 1.0.	Critical review of the capabilities and weaknesses of the blueprint together with the customer	10	In progress (25 %)

T6 Writing of the status review report	Writing the status review report in as described in course schedule	25	Completed
T7 Programming the final software	Implementing the plan	175	Not started
T8 Writing of the final report	Writing the final report in accordance with guidelines of the course and the client.	60	Not started
Total		435	

The Gantt-chart reveals that some activities are behind the planned schedule. The planning of the simulation model turned out to be a great challenge for the research team but anyhow, the task is about to be completed by the end of March at the latest. The final selection of the software tool is still pending although MatLab seems to be far the most suitable candidate for the purpose of this research. The final decision considering the simulation tool will be made as soon as the task T4 "Planning the simulation model" is completed. Naturally, after the bottleneck task T4 has been completed, also task T7 "Programming of the final software" can be started.



Picture 1: Gantt-chart illustrating project execution timeline

Project risks – everything in control so far

None of the risks described in the project plan have realized during the first months of the project, although the research team realized that the schedule of the course is rather tight after all. Therefore, a risk that the schedule of this project does not hold was explicitly added to the risk table so that the research team does not forget that adequate working hours are needed to get all required tasks completed by the deadline of the course. The risks of the project together with new remarks and revised probabilities are summarized in Table 2.

Risk	Mitigation	Effect if occurs	Remarks	Revised probability
A group member becomes disabled to complete his duties	• Working in groups • Tight communication t	• Time delays • Quality may suffer • Others must work harder	• The fourth member of our group joined us a month ago • Motivation of the group is high	**Medium**
Inability to learn programming	• Reserving enough time for learning	• Deliverable are of poor quality • Workload increases	• Team is at least to some extent familiar with MatLab	**Medium**
The scope of the project is poorly defined	• Defining and assessing the simulation together with customer before programming	• Customer dissatisfaction • Workload explodes	• Frequent meetings with the client have helped in defining the manageable scope	**Low**
The resulting model is too heavy or not relevant to customer	• Defining and understanding customer needs	• Customer dissatisfaction	• Frequent communication with the client tackle the problem	**Medium**
Schedule does not hold	• Adequate allocation of working hours for the project	• Delayed / sub-standard final report	• NEW risk	**Medium**
Inability to link sub-problems together mathematically	• Information search and consultation of course personnel	• Poor quality and customer dissatisfaction	• NEW risk	**Medium**

Table 2: Revised summary of the identified project risks

Annex A – Simulation model

The task assigned to us is to simulate a logistic network where the road network may be damaged and can be prepared. We have divided this into four sub-problems: 1) what triggers the demand for resupply from the nodes (batch size and service level problem) 2) how are the orders distributed to hubs (scheduling problem), 3) how does the transportation vehicle choose which way it's going to drive there (routing problem) and 4) how to model the delay and changes in the route network.

We have decided to approach the triggering of resupply demand problem in the following way: 1) the node calculates the optimal batch size based on the information about average service time 2) node monitors its stock levels and sends out orders so that it would avoid out-of-stock effect. Batch size problem has been discussed in length in the literature. The potential problem areas may stem from the varying necessity of different products. For instance water is more critical than food so the optimization algorithm should be able to understand this. Thus the target function may have to be some sort of utility function.

Distributing orders to different hubs is also a tricky question. We haven't been able to find an optimal solution or algorithm for scheduling problem and thus we have decided to use a heuristic rule which allocates the orders to servers (hubs): FIFO queue(s). There are also other heuristics which can be employed here but the idea of this part of the model is that the orders are scheduled in some way or another. The FIFO queue allocates the demand to the server when it has the necessary products and necessary transportation capacity to fulfill the order (becomes unblocked). The FIFO queue may be also arranged so that it doesn't allocate the order to first server which becomes unblocked; if it waits for e.g. one round another server may complete the order more quickly.

As the server receives an order it fills it must find its way to the node. Routing problem would not be an issue if the road network would be constant all the time. Since the road network is constantly changing server must optimize its route every time step. The optimization is done using a simple dynamic programming algorithm which minimizes the time to the node. Algorithm calculates each possible route to the node and chooses the shortest. The time it takes to get to the node creates a delay. If the road network were constant, the program could send an information to the node saying your warehouse levels will be increased by x in y rounds, but since the road network may change each time step this may not be the case if a road goes bust while a vehicle is on it. Thus the output is passed on to the road network subprogram.

The road network subprogram has two purposes: 1) it enables the changing road network 2) it enables the modeling of the repair forces. Our idea is that a road consists of "nodes" each length of a time step. So if it takes two time steps to get from a hub to a node it, the rode consists of two "nodes". If the road breaks it creates a demand for repair forces and triggers an order for repair forces. The demand goes to the queue and is serviced by the repair forces as soon as they become available. The node has also warehouses for vehicles. Each time step some amount of vehicles enters the node and some leave. If the road brakes down, the vehicles cannot move so they are stored in the node. Figure 1 summarizes the overall functionality of the simulation.

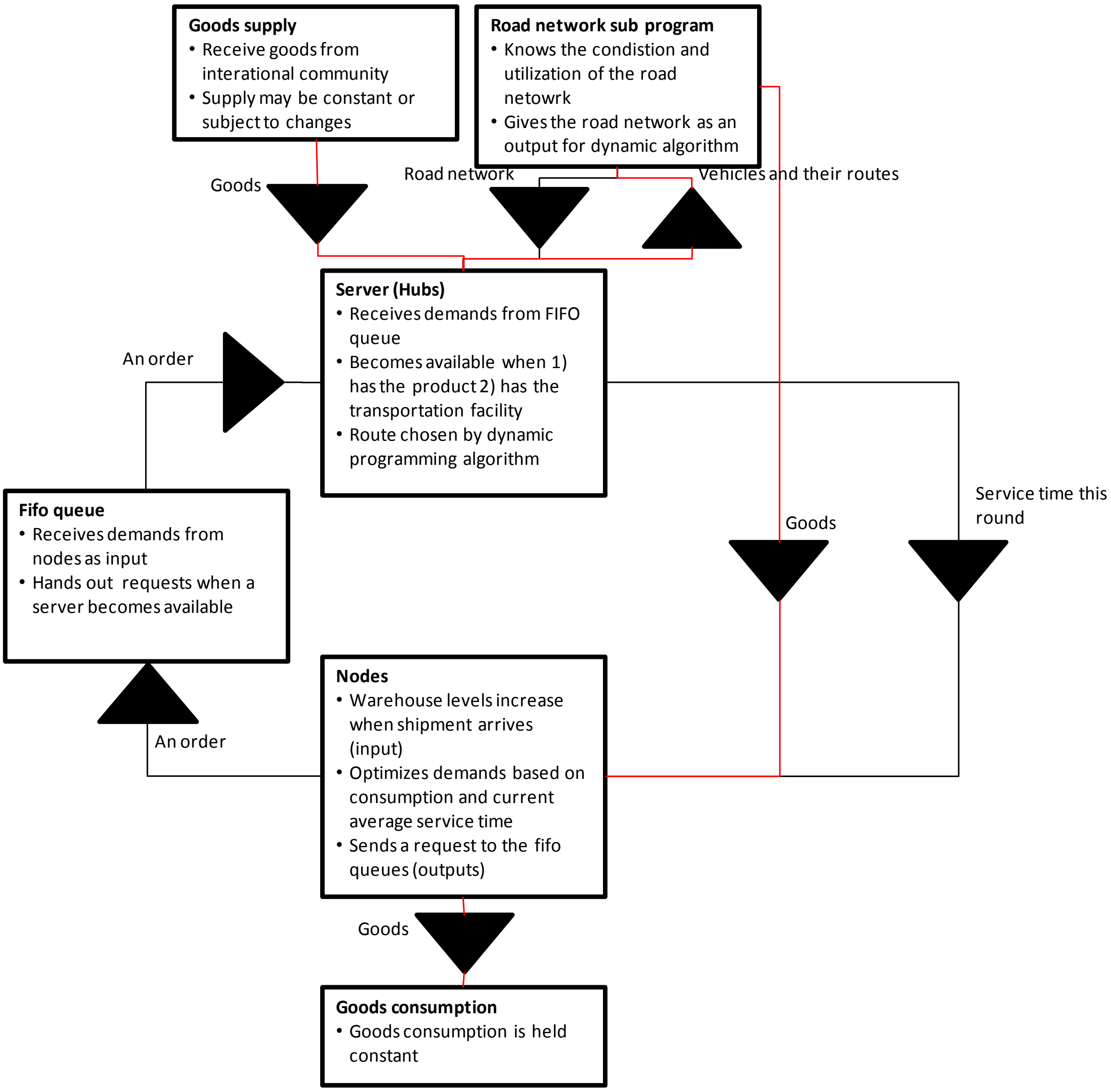


Figure 1 Simulation model

When orders come from nodes, there must be a queue management method that determines in which sequence and from which hub the nodes are served. When the objective is to minimize the suffering, first-in-first-out (FIFO) queue management method is the most obvious choice. Because all the orders follow the common re-order point and order size rules, the slack time between the first possible date of delivery and the moment when inventory comes empty is same with all the nodes. In addition, we can assume that every new sequential day without certain commodity increases the suffering more than the preceding day. Because FIFO method minimizes the longest response time, although it does not necessarily minimize the overall waiting time of all the orders, it is the best method when all the nodes are equally important and the distress among people increases together with the days of shortage of supplies.

Before allocating orders to hub's FIFO-queue, it must be determined from which hubs it is fastest to fulfill the orders. We have to build an optimization algorithm between nodes and queues that calculates the most efficient order allocation plan that take into account current and forthcoming delivery capacities of the hubs as well as the distances between nodes and hubs.

Figure below demonstrates how FIFO method works.