Summary

Pneumatic tubes, also known as capsule pipelines or Lamson tubes, are money-saving transporting systems in which cylindrical containers, carriers, are propelled through a network of tubes by compressed air or by vacuum. Blowers are the devices used to provide the vacuum and pressure actions needed to move carriers through the system.
Deerns raadgevende ingenieurs bv notices that pneumatic tube systems play an important role in material handling in many hospitals and that the use of pneumatic tube systems is growing every year. Particularly systems that consist of multiple subsystems, each containing multiple stations and diverters, are systems that are frequently being installed in hospitals.
Deerns designs many large hospitals and want to provide her constituents with an optimized lay-out of the pneumatic tube system by predicting the capacity and waiting times of the system.
To be able to provide her constituents with the best advice Deerns has formulated a design task to develop a simulation program for pneumatic tube systems, using Delphi/Tomas. Deerns also formulated a research task to analyze the lay-out, designed by Deerns, of the pneumatic tube system of the Jeroen bosch Hospital by using the developed simulation program. Besides assessing the existing design study into optimising the design is also done.

After a thorough literature- and practice research it is clear how pneumatic tube systems work and what the most important performance indicators are. The waiting times, delivery times and the sizes of the buffers are the most important performance indicators and are determinative for the performance of the system. The transportation speed and the distribution of the system have the biggest influence on these performance indicators, the influence of the other input variables is negligible small.

Now the system and the performance indicators are known the modelling part of the design process can be started. In this phase of the design process it is important to implement only the vital elements and processes of the real system and to filter the unnecessary ones. When the different, important, elements and processes of the real system have been implemented, and when necessary simplified, in the model the programming phase is started. The models and flow diagrams made in the modelling phase are now being used to write the Delphi program code. In this programming phase the User Interface of the simulation program has also been designed. The graphics, the ease of use, the simplicity of the program and the required output data have been key factors in designing the User Interface.

To assure that the simulation program has been designed, modelled, coded in a correct manner and to assure that the model reflects the real pneumatic tube systems correctly, the model and the program have been verified. The validation process of the simulation program, unfortunately, was impossible to complete because of the lack of specific practice data of real pneumatic tube systems. The use of simulation programs at designing pneumatic tube systems is an entirely new way of designing and it needs other practice data then the current design method. These newly required data are at present not registered by the control systems of the pneumatic tube systems.
An exhaustive verification process has shown that the developed model and simulation program have been modelled and programmed correctly. The results of the simulations can be used with sufficient certainty as reliable data to analyze pneumatic tube systems.

With the help of the simulation program a graph can be made in which the waiting- and delivery times is presented for a certain offer of containers per hour. When looking at this graph it is immediately clear what the maximum offer of containers per hour is and for how many containers per hour the system will be stable. By constructing such a graph for several concepts it is possible to compare these concepts and select the best performing one.

The simulation program is used to analyze the concepts of pneumatic tube systems but does not create these concepts itself. To create the ultimate concept it would be ideal if the simulation program itself searches for the ideal lay-out for a certain pneumatic tube system. To do so the program should create, examine and compare all possible concepts.

After al necessary system data, lay-out and distribution, have been put into the simulation program the design of the pneumatic tube system of the Jeroen Bosch Hospital has been analyzed and optimized.
It appears that the design has an average waiting time of 138 seconds at the given distribution of 136 containers an hour. When the distribution is expanded to 164 containers an hour the average waiting time of the containers increases exponentially. When the distribution is lowered to 82 containers an hour or less the average waiting time is stable at 25 seconds.

After an iterative process of redesigning the design two concepts perform significantly better than the Deerns design. Both optimized concepts have a reduction of the average waiting of more than 50% compared to the Deerns design. Both concepts have exponentially growing average waiting times when the distribution reaches an offer of 180 containers an hour. When the distribution is lowered to 100 containers or less the average waiting times of both concepts are stable at 11 seconds. Which of these two concepts should be chosen depends on the demands that are made by the constituent. Whether financial considerations or minimum average waiting times are more important is the key in this decision.

The most important adaptations to optimize the Deerns design of the pneumatic tube system of the Jeroen Bosch hospital are:

- Take the station "Radiologie" from subsystem three and create its own subsystem.
- Transfer four stations from subsystem six to subsystem three.
- When the total number of subsystems has to remain six, subsystems four and five have to be combined and become one subsystem. In combination with the first two adaptations this results in a system that performs more than two times better.
- When the total number of subsystems is allowed to become seven, subsystems four and five stay separated from each other. In combination with the first two adaptations this results in a system that performs more than two and a half times better.