Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	David den Ouden
Student number	
Telephone number	
Private e-mail address	

Studio		
Name / Theme	Computational design	
Main mentor	Pirouz Nourian	Computational design
Second mentor	Petra Heijnen	Graph theory
Argumentation of choice of the studio	Computational design is one of the most important reasons why I choose Building Technology in the first place. It keeps me interested and enthusiastic. Furthermore, I would like to work with computational design after graduating.	

Graduation project	
Title of the graduation project	David and the vegetable factory

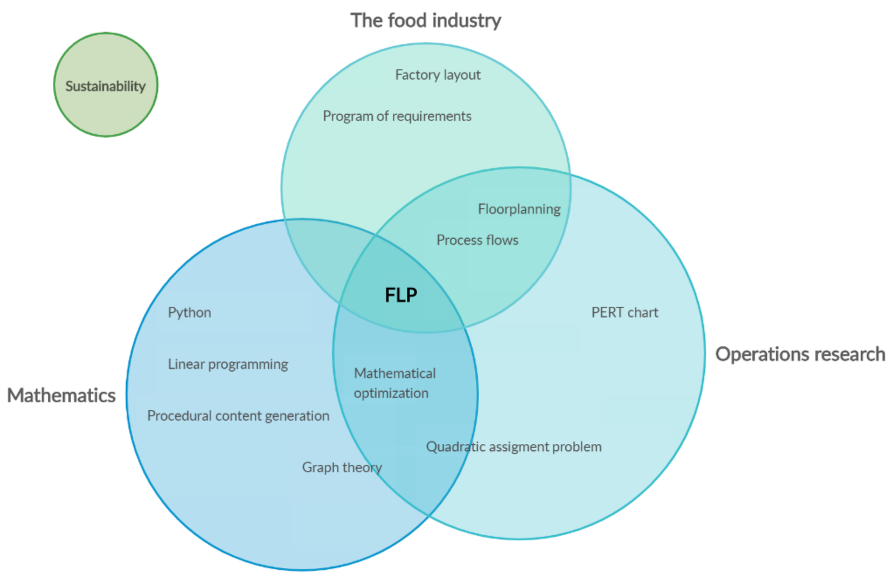
Goal	
Location:	Not applicable
Context	In a world that is getting more complicated, so are the floor plans of numerous buildings. Especially for industries, a layout of the floor plan can really define how profitable a factory is, it is estimated that in total 20-50% of total operating expenses can be related to the material handling costs and the layout of a factory [5]. Furthermore, early changes in the design of a layout have a big impact on the final design and can be very profitable, especially considering that changes in a later stage are significantly harder, costlier and more complicated to perform. Chwif et al. [9] suggest that the optimal location of facilities is one of the most important issues that should be resolved early in the design stage. In the past, when layout were less complicated, optimizing the location of facilities was not as much of an issue. However, after the second world war, operations research and with the optimizing of processes arose. Optimizing various process has been a big issue ever since, and so too the optimization of the layout of facilities emerged which became known as the Facility Layout Problem. With the development of powerful computers

that are available to the wide public, a window of opportunities opened to be able to solve these ”FLP’s”.

The motivation of this thesis comes partly from personal experience of designing factory layouts, where my work at the company Dapp Project-management in Food has taken me through the world of designing food factories. In this world, the use of computation to design is hardly used, traditional hand-drawings are the main source of designing and communicating plans. This comes with problems like long wait times to change certain details or entire plans. This let me to believe that a computational implementation of designing the layout could give a huge benefit to the industry. Besides potentially saving time and money, a faster and more adaptable "computational tool, if you will, would also ultimately lead to a more sustainable workflow, since time and money and thus emissions could be spent more efficient. A sustainable way of living is something that is absolutely necessary at the present date, in order to express its importance, a quote by the late Professor Stephen Hawking will be presented:

"Global warming is caused by all of us. We want cars, travel and a better way of living. The trouble is, by the time people realize what is happening, it may be too late. ... both effects (deforestation and melting of the ice caps) could make our climate like that of Venus: boiling hot and raining sulphuric acid, but with a temperature of 250 degrees Celsius. Human life would be unsustainable."
[3] p148-149

The context of this thesis takes root in a number of fields, where three different fields can be marked as major. These three fields are: operations research, mathematics and the food industry. The common binder of these fields is the facility layout problem, which will be elaborated upon in great detail further on in this thesis. Other fields that fall under the three major fields named are all shown in the Venn diagram in the figure below. It is known that there are other fields which are closely related, including but not limited to: game theory, operations management and supply chain management. However, they fall out of the scope. Hence, they will not be dealt with in this thesis.

	
The posed problem,	Even though there is great value to be added by computational design to improve the design performance, it is hardly ever used in the early design [1]. When these computational design methods are in fact used, they tend to be only be used to verify the conceptual design, instead of being used to explore the different solutions which could be generated [2]. In the field of the food industry, computational design is not a known concept, instead, most of the work is done by hand. Introducing the power of a 21st century computer into the design process could lead to great benefits. However, this computational design should be presented in such a way that is comprehensible by its users, which are the people that work on designing the layouts of the factories. These people have minor experience with computational design and thus a tool that copes with this lack of computational knowledge should be developed. The problem lies in how to develop such a tool. As mentioned before, the facility layout problem boils down to arranging facilities in such a way that the material handling cost are minimized. This problem, however, quickly becomes NP-complete when increasing the number of facilities. Johnson [4] has showed that when the number of facilities becomes larger than 15, the facility layout problem becomes a NP-complete problem. This means that with increasing number of facilities the computational time required to find the absolute best solution is increased by 2^n. Since the optimal solution for a larger number of facilities becomes virtually impossible to reach, (meta)heuristic methods have been developed in order to find a near optimal solution in a reasonable time spawn [30]. The problem of NP-completeness can thus be resolved by applying (meta)heuristic approaches in order to achieve near optimal solutions. The formulation of the problem in mathematical terms is the generation of a layout for a food processing factory, while trying to optimize the material handling cost as seen in equation(1.1)[47] and keeping the problem compact (e.g. reduce the amount of empty space), where c_{ij} is the transportation cost for transporting between departments i and j , f_{ij} is the flow between those departments and d_{ij} is the distance between

	them. The problem will be tackled as an unequal-sized problem in order to maintain accuracy and as a static problem in order to simplify the problem. $MinimizeF = \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij} f_{ij} d_{ij} \qquad (1.1)$
Research objective	Considering the problem statement the research objective then becomes to develop a tool for designers of factory layouts to use to generate the layout of a factory. To be more precise, this thesis will take the specific case of a vegetable processing factory. This tool should be user friendly, even to a user with little computational experience. To achieve this, the facility layout problem must be formulated and then solved using meta-heuristic methods since exact methods would impose a computational solving time that is just to vast.
Research questions	The posed problem statement and research objective lead to the following main research question: *"How to computationally generate a layout of a vegetable processing factory given a program of requirements and flows between facilities as a matrix using a mathematical approach, minimizing the travel distance of goods needed for a product to be manufactured?"* This main research question consequently leads to the following sub-questions concerning how to answer the main research question but broken down in steps. They are as follows: (1) "How can the facility layout problem be formulated?" (2) "What computational approaches have been proposed to solve the FLP in the literature?" (3) "What are the requirements of a vegetable food processing factory and how can these requirements be formulated mathematically?" (4) "To what extent do the proposed methodologies in the literature comply with this specific case of the FLP?" (5) "What are the main objectives and constraints to satisfy considering the generation of a layout for a vegetable processing factory with a given program of requirements and flows between facilities?"

Process

Method description

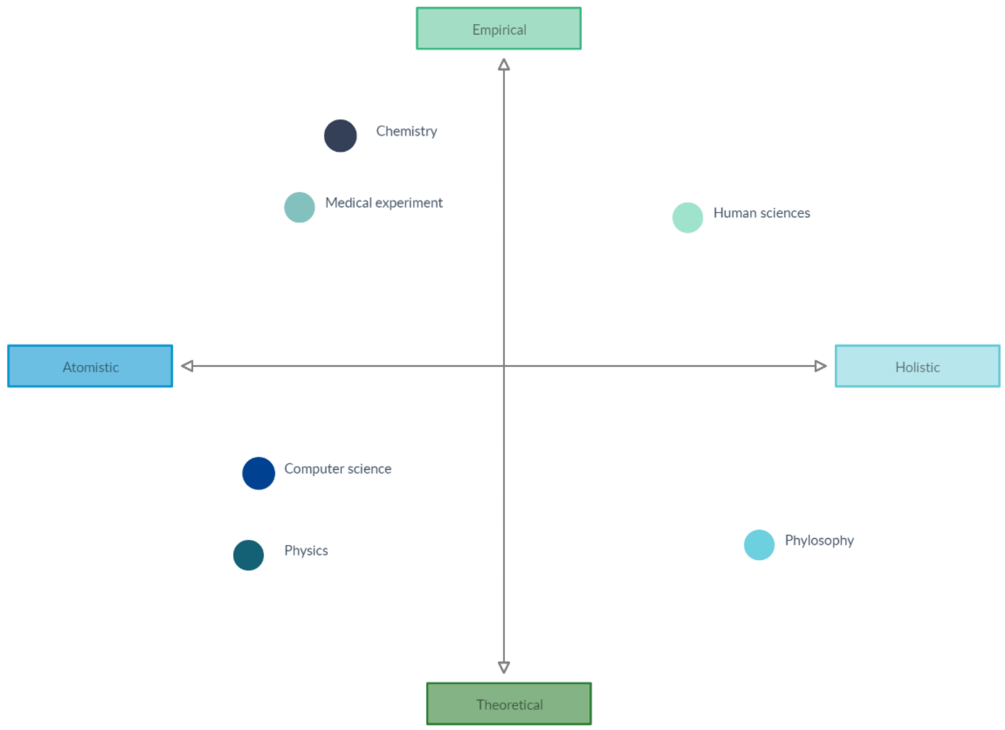
This section will go over the methodology of this thesis. This research methodology is not to be mistaken with the proposed methodology that will be addressed in section four. The methodology of writing this thesis finds is fundamentals in researching through design, which is vastly different then for example the researching of medical chemistry experiments where an experiment is conducted and certain data leads to certain conclusions. However, same as this thesis, both fall into the same category of research. The difference can best be explained by the diagram in figure 2.1, which

shows the scale of different types of research. The scale has two directions, one from atomistic to holistic and one ranging from theoretical to empirical. The example given before would be defined to be both atomistic and empirical, as a chemical experiment would be considered to be atomistic, it is about something that is tactile and it is well defined subject. Next to that it is also considered empirical, because it is about a clear experiment with clear results. On the exact other side of the scale would be philosophical research, which is neither atomistic or empirical, but holistic and theoretical because it deals with a whole of something and not something that is narrowed down and the experiment and expected results are not as easy to predict and black and white as with an empirical approach.
The approach that is used in this thesis is based on a theoretical and atomistic standpoint: research through design. The subject that is dealt with is well defined but the results to be expected are hard to predict and thus different design must be evaluated in order to find what works and what does not.

The methodology consists of four parts. The first part is a literature study of the facility layout problem to get more acquainted. The goal of this stage is to find out how FLP's are formulated and how they are solved and what different approaches there are to going about this. This knowledge of previous research that has been done to solve the facility layout problem will form the basis of the next steps. The second part involves the study on an existing food processing factory and assessing its properties and needs. This way, criteria can be formulated which a potential method should be able to fulfill (e.g. The amount of departments). Thirdly, taking into consideration the knowledge gained in the first two steps, nine methods that are thoroughly researched and presented in appendix B will be analyzed based on the criteria and requirements gained from the study in the second part. This way, all discussed previous methods will be tested and the results will summarize how well that method would work on this specific problem. Besides that the factors in which a method excels and doesn't excel become clearer through this analysis. Fourthly, the experimental design stage can begin by the proposal of a method on how to solve the facility layout problem in this particular case. The conclusions from part three are enough to identify which method work well in this particular case and a proposed method could be based on one or more of these analyzed methods. Although the methods found in the literature could give a basis for my own proposed method they should not be copied blindly. This is for several reasons. Firstly, even though the problems might look the same, they will probably be different in some aspects and that would favor tweaking the method. Secondly, the results of the methods in the research paper might be sufficient, but the authors most likely acknowledge some points of improvement, if possible, they should be taken into account. Thirdly, in order to push the boundaries of scientific knowledge, itis unfavorable to re-enact another's work. As the last step, the method is then carefully modelled in python in a Rhino/Grasshopper environment [3][2] where a feedback of tests loop improves the model until the results are satisfactory.

The assessment of the proposed methodology in sections four through eight are an important part of this thesis, for without a good assessment how could we be expecting good and reliable results? This assessment comes down to two important factors, which are verification and validation.

Verification of a method is about the question: How do we make the things right? It is about whether, in this case, the algorithm that was written is working efficiently. The algorithm should be doing what it should be doing and in order to find out if it is, tests should be written and conducted to study its behavior. A algorithm that gives good results could still be an algorithm that gives false results, hence the importance in the verification of the algorithm/method. This verification of a algorithm is known as test-driven-development. Test are conducted on situations where the answer the algorithm should be given is obvious. This could either be simple problems that can be verified by a hand calculation or it could be a larger problem but one with a lot of symmetries. Other tests that should be conducted are tests in extreme situations in order to find out if the algorithm still performs well under these situations.
Validation of a method is about the question: How do we make the right things? At first glance, it is closely related to verification, but with validation, we are not concerned any more with if the algorithm is working correctly, because it is assumed with verification that it is. Validation is about the effectiveness of the algorithm, whether it is giving results that are satisfactory. To test this, as specified above, toy problems can be used in order to find out how well the algorithm compares to already solved problems using different algorithms. Another method is to compare the results with a ready built factory.



Literature and general practical preference

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Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

   The relation between my graduation topic and master track is the use of computational design to generate a layout for a building. Although the building in this case is a factory, and some might not consider this part of architecture, it is still a building and the tools developed will lead to knowledge that is not only applicable to factories, but to any building or any layout.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

   Since the facility layout problem was first introduced some fifty years ago, it has never truly been solved, some problems might have reached a global solution but those problems remain small. Ideally, this thesis would provide new insights into solving the facility layout problem, even though if it might only be for a factory. By building upon the already existing knowledge I can expand the scientific framework of the facility layout problem.