Summary

In production and warehousing environments there is an increasing demand on efficiency. Automation of warehousing systems can contribute to this demand. This research focuses the presentation of material handling equipment, specifically Automated Storage and Retrieval Systems. To avoid unnecessary palletizing and depalletizing after batch production possibilities on directly store unitized products into storage locations are investigated. This research presents different Automatic Storage and Retrieval Systems that are capable of the handling of small goods, which can be applicable in the food and beverage industry.

Within a warehouse there are four basic processes the products undergo within the warehousing process; receiving, storing, order picking and shipping. To understand the design and operational problems in a warehouse six different measures to assess the performance of a warehouse are identified by Groover; *storage capacity, storage density, accessibility, system throughput, utilization and availability.*
These measures are important to determine the requirements a warehousing system should suffice. The warehouse characteristics can be viewed from three different angles according to B. Rouwenhorst: *the warehouse processes, the warehouse resources and the warehouse organization.* With respect to the level of automation three different types of warehousing systems are distinguished: *manual-warehousing systems, automated warehousing systems and automatic warehousing systems.* This research presents concepts with as less manpower as possible, but sometimes manpower will be used.

There are three different levels on which decisions concerning the design and operation problems of a warehouse have to be made: *strategic, tactical and operational.* Choices concerning which AS/RS to implement are on a strategic level, because the possible investments are very high and long term. This research showed which systems are currently 'on the market' and commonly used in the warehouse industry.

A standard AS/RS consists of the following components; *storage structure* (rack framework), *Store,- and retrieval machine, storage modules, pick-and-deposit stations and a control system* (usually a Warehouse Management System).
AS/RS are used in many different industries and for the handling of relative small goods (no pallets) the following systems can be used:

Miniload:
A miniload is a crane mounted to a rail between two racks and is able to store and retrieve products. The retriever (the apparatus that does the storage and retrieval from the racks) is able to move horizontally and vertically so all storage locations in the racks are accessible.

Multishuttle:
Multishuttle systems exist of multiple shuttles that are able to access the different shelves on different heights via a lift. Each level contains rails to guide the shuttle. In this configuration it is possible to perform multiple storage and retrieve assignments at the same time.

Carousel system:
The basic principle is complete storage racks are able to rotate horizontally or vertically to bring a specific container up front where it can be placed on a conveyor.

Quad system:
With a Quad system it is possible to retrieve or store four SKU's simultaneously. The basic principle is the same as the multishuttle, now with different quad systems above each other. These are not able to change height via a lift.

These solutions seem to be applicable to the example case, which has the following figures (partially based on assumptions to illustrate what influence parameters may have on the decision of an AS/RS):

- Product dimensions of 100x100x100 mm up to 400x600x400 mm (LxWxH)
- The small products are loaded into Stock Keeping Units (SKU's) with the dimension of 400x600x400 mm, because the small products can not be handled by an AS/RS

- One production batch contains +/- 2500 production units and it takes one hour to produce this
- Six situations are presented with a desired storage capacity of 2, 3 or 4 production days and with 3, 4 or 5 production lines

With these data the minimal storage capacity for a warehouse can be calculated and the number of cycles an AS/RS has to make in order to handle all SKU's. With the use of these data a miniload appeared to be suitable.
Before and after storage of products in the AS/RS other equipment can be used such as robots, conveyors and AGV's. It is also possible to use manpower instead of robots.

Within a simple cost calculation two AS/RS concepts are compared: one with manpower and one with robots. In this simple calculation the concept with robots will pay off within four years. This is a simple calculation where energy costs, depreciation, reservations etc. are not taken into account.

Concluding it can be said there are numerous AS/RS configurations, which can all be tuned upon customer needs. Most concepts are modular and thus easily expandable if future growth is taken into account. The parameters identified by Groover are important to concern before a design phase starts. Discovering possibilities on AS/RS it appeared to be hard to get financial figures. Some cost indications have been mentioned but suppliers indicated projects are always tailor made and therefore it is hard to provide financial indications. Also suppliers are not always prepared to provide financial information.
An example case is used to be able to make a comparison between a conceptual design with the use of manpower and a design with the use of robots.
To be able to make a decision on the automation of a warehouse data are needed to determine the requirements of an AS/RS. The goal of the research was to present Automated Storage and Retrieval systems that are able to store and retrieve small product units. Presenting four different systems and some of their variations does this and the case example gives a simplistic view on some performance measures that are taken into account. However each individual business case has to be extensively studied to be able to choose a configuration that meets all requirements.