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A Build-or-Lease Case Study for a Potential New Warehouse due to Increasing Storage Capacity Requirements

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***Abstract*—A build-or-lease decision for warehouse is a crucial success factor for future product availability. The research deals with a logistics study for a crop science company. The need for it stems from increasing production volumes which cause storage space shortages and high warehouse utilizations. Before deciding for or against a warehouse, it has to be analyzed how much storage space is required and where the new warehouse should be located. The research evaluates if it is preferable to either build or lease a potential new warehouse. A comprehensive literature review reveals considerations for carrying out logistics studies by means of a potential analysis. A database serving as a material requirements planning tool calculates future storage requirements based on a worst case scenario. The optimal warehouse location was found by means of the heuristic center-of-gravity technique. A sensitivity analysis has been applied for the economic evaluation. The research concludes with a recommendation on the most economical alternative, which is to lease a warehouse with 1085 pallet places at the determined optimal location. The research considers static data only. Further research should consider dynamic behavior of the system, or factors which are typical for the industry (e.g. environmental impact, morality).**

***Keywords*—Make-or-Buy Decision; Potential Analysis; Warehouse Location; Economic Evaluation**

I. INTRODUCTION

The case study was conducted in one of the world's leading crop science companies in the area of crop protection, non-agricultural pest control, seeds and plant biotechnology. The company currently holds several buildings for administration, solid and liquid production, packaging and the related warehouses. In addition, the site holds two empty plots. The production volume has increased significantly year over year since 2007 and is depicted in Fig. 1. It is forecasted to keep this trend for the next years.

This development led to increasing capacity requirements and raised the question if the site shall be extended by another warehouse (WH) to cope with the increasing demand. Therefore, a logistics study is conducted to review the capacity requirements. The purpose of the research is to find out whether a storage capacity extension is necessary and, if yes, how this should be realized. Options to address the capacity requirements are examined by means of a make-or-buy study; whereas make refers to build and buy refers to lease. A new WH could be built on the site or leased from an external logistics service provider (LSP) in a preferred location.

A holistic assessment of the logistics processes ranging from delivery of raw materials through production to distribution ensures reliable and comprehensive findings supporting the outcome of the research. The result will support the company in making a final decision about further steps and the budget.

Besides the practical and academic benefits, the importance of the research for the company is obvious. A decision which includes a high monetary investment should take into account all influencing factors which pertain to the situation and could have an impact on the decision. Therefore, the decision should be made based on well-examined and profound information. Otherwise, a new WH might be built although it is not required.

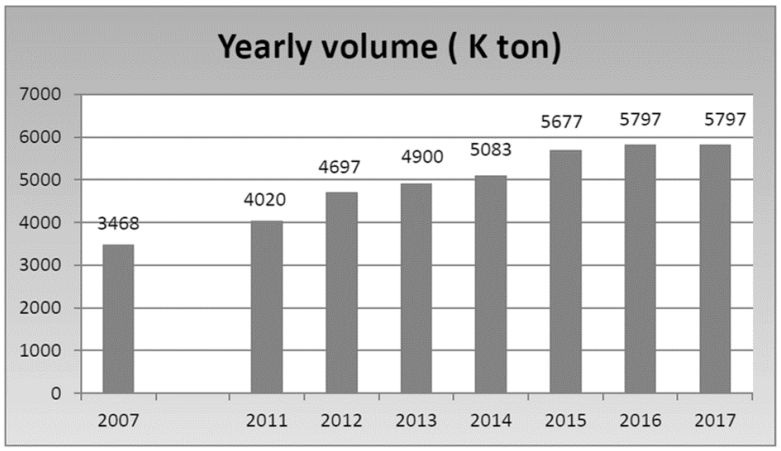

Fig. 1. Sales development over 10 years

The literature review shows that there are many methods for analyzing logistics processes and structures. A lot of these theories are applicable for the underlying problem statement and could be conducted on a very detailed level. The reason is that a lot of factors can influence the outcome of the logistics study. However, this approach would be beyond the scope of the study. Hence, we are looking at the big picture in order to come to a conclusion. The primary theories used are potential analysis and make-or-by decision. The potential analysis as a broad method compares a company's operations with certain requirements by examining the processes, structures of logistics networks and the performances. It is divided into these sub-theories accordingly. The process analysis determines essential logistics processes and their relation to each other by documentation of the material flows through the different stages of storage and production. It further ensures the completeness and accuracy of master data or correct information about stock levels. This lays the groundwork for process modelling and further analyses. The structure analysis examines whether the given network structure satisfies present and future demand. It shows which improvements can be achieved by changing current structures (e.g. transportation network) or setting up new systems (e.g. warehouse). A WH functions as an intermediate point in the supply chain. Russel and Taylor [6] state that the physical location of a facility has a tremendous impact on logistics decisions. This is mainly due to the transportation costs, but also proximity to markets. The outcome of the structure analysis is the input for the performance analysis. It evaluates at which costs and with which resources the requirements are fulfilled. The alternatives are quantified in monetary terms and compared by means of an economic evaluation.

II. Objectives

The two main objectives this study will achieve and the outcomes that will be seen as a result of achieving these objectives are stated in the following TABLE I.

TABLE I. Objectives of the Research

Objective	**Outcome**
Evaluate storage space requirements	Determination of bottlenecks to see which warehouses operate beyond capacity
	Future storage capacities based on demand forecast
Find the best alternative for a potential warehouse extension	Optimal warehouse location
	Economically preferable alternative (extending local site vs. outsourcing to logistics service providers)

III. Potential Analysis

The theory of potential analysis reflects quite well the research methodology because it breaks down research areas in smaller analysis parts. A potential analysis discovers deficiencies of the existing system as well as suitability of a potential new system. It reveals whether it is advisable to modify current processes and structures or whether it is better to implement a new system, which can fulfill the expected demand and achieve the required performance.

In order to achieve the required system performance and ensure that no useful option is ignored, a systematic analysis based on proven methods is substantial. Gudehus and Kotzab [3] compiled a comprehensive list of the general steps to look at when planning and analyzing a system. Relevant steps to consider for the underlying logistics study are:

- definition of objectives (what should the logistics study achieve?)
- documentation of processes (capture base data)
- data collection and analysis (ensure completeness of data and correct analysis)
- identification and analysis of requirements and restrictions (consider frame conditions and expected demand)
- quantifying performances (assign monetary units to alternatives)
- conception of possible system solutions (identify ways how increased capacity requirements can be satisfied)
- budgeting of investment and operating costs (identify all necessary investment and operating costs for make and buy alternatives)
- selection of the optimal solution (recommendation based on analyses).

Depending on the scope or the size of the company, a potential analysis takes between four weeks and three months. Compared to the achievable results, the expenses for such an analysis are low and the payback period of the investment is generally less than one year. The outcome of the potential analysis is usually a report which presents the recommended improvements or suggestions for new concepts and projects. This serves as basis for the decision maker to decide which projects are particularly promising and, therefore, should be planned and realized. A potential analysis does not provide solutions to problems. It offers strategies to reach a specific goal or to find the optimal solution. Strategies can refer to: design solutions and optimization of systems, utilization and allocation of planned and existing systems, scheduling or operation of systems. The strategies are determined by the goals, required performances and restrictions. Consequently, networks, systems, processes and general solutions can be delineated only after applicable strategies have been developed.

Some goals for the underlying logistics study are minimizing transport costs, storage space or path lengths, and maximizing utilization of transport networks or store capacities [3].

Within the scope of a logistics study, capacities, performances, network structures or processes are evaluated. Potential analysis is used as one of the main research approaches because it allows a structured method by analyzing the processes, structures and performances.

A. Process Analysis

Schenk et al. [7] define logistics processes as integral transport, handling and storage processes which constitute a significant cost factor. Russel and Taylor [6] define process analysis as a systematic examination of all aspects of a process to improve its operation. The basic tools of process analyses are process flowcharts, diagrams and maps. Scholz-Reiter et al. [8] state that a process analysis is the basis of any process modeling endeavor. Dahlgaard et al. [2] add that the goal of a process analysis is, among others, to evaluate the logistics processes from the supplier to the receiver of the goods. Therefore, a complete documentation and critical evaluation of current logistics activities is required. This includes the following topics: logistics units (use of load carriers; dimensions and capacities; filling degrees of the load carriers), available and correct logistics master data, costs (possibilities to save logistics costs without reducing service and performance; main logistics cost drivers), stores and stocks (storage locations; buffers; availability of items), quality (service quality; flexibility of processes), logistics chains (distribution channels; flows of material, bundling of deliveries), make or buy (core competencies of the company; tasks to be outsourced).

B. Structure Analysis

For the underlying logistics study, WH structures with their stock compositions as well as distribution structures are of importance. The structure analysis determines whether a given network structure can fulfil present and future demands. Connections within the logistics network have to be determined and visualized. By this means, weaknesses in the system can be recognized and potentials for improvement derived [2]. On the basis of the results, it is possible for the decision maker to decide which of the improvement opportunities can be achieved by modifying current structures or setting up new systems [3].

The task of a structure analysis is to investigate the following topics:

- location of stations (optimal places of plants, WHs and delivery stations)
- allocation of functions (tasks and stocks among WHs)
- degree of centralization (local and central functions; possibilities for consolidation of stocks).

Structure requirements are often fixed points and determined by the sources and sinks. In contrast, intermediate stations (e.g. WH) can be changed. Their locations and number are design parameters for network improvements. The most important cost drivers within these networks are the delivery frequencies [3]. The result of the structure analysis is a recommendation for improving the network structure or modifying entire logistics networks. It also determines whether it is advantageous to localize or centralize certain functions and stocks, and provides estimations about possible cost improvements.

Two research steps are based on the principles of structure analysis. First, the WH structures are examined to see if the available space is sufficient to hold future quantities. Second, the distribution network structure is examined to find an optimal location for a potential new WH.

C. Performance Analysis

The performance analysis investigates at which costs specific business operations fulfill the requirements. Performances can only be evaluated if they can be measured. However, measuring the performance is only the first step to performance management. The performance metrics are rather the input for further improvement processes. This is essential for translating the company's objectives into planning processes [5]. Analyzing the gap between current and desired performance helps to determine whether processes need to be restructured.

As part of the potential analysis, performance analysis evaluates the financial performance of both build and lease options by means of an economic evaluation. The procedure leads to the option with the highest economic potential.

IV. RESEARCH FRAMEWORK

The approach to solve the research problem is based on related literature and theories. The framework in Fig. 2 illustrates how the objectives of the research will be achieved. It shows the basic outline of the methodology, how the steps relate to each other, which data is required in every step and the measureable outcome of each analysis type. In general, the idea of a potential analysis is utilized to approach the research problem and lay the groundwork for a build-or-lease decision.

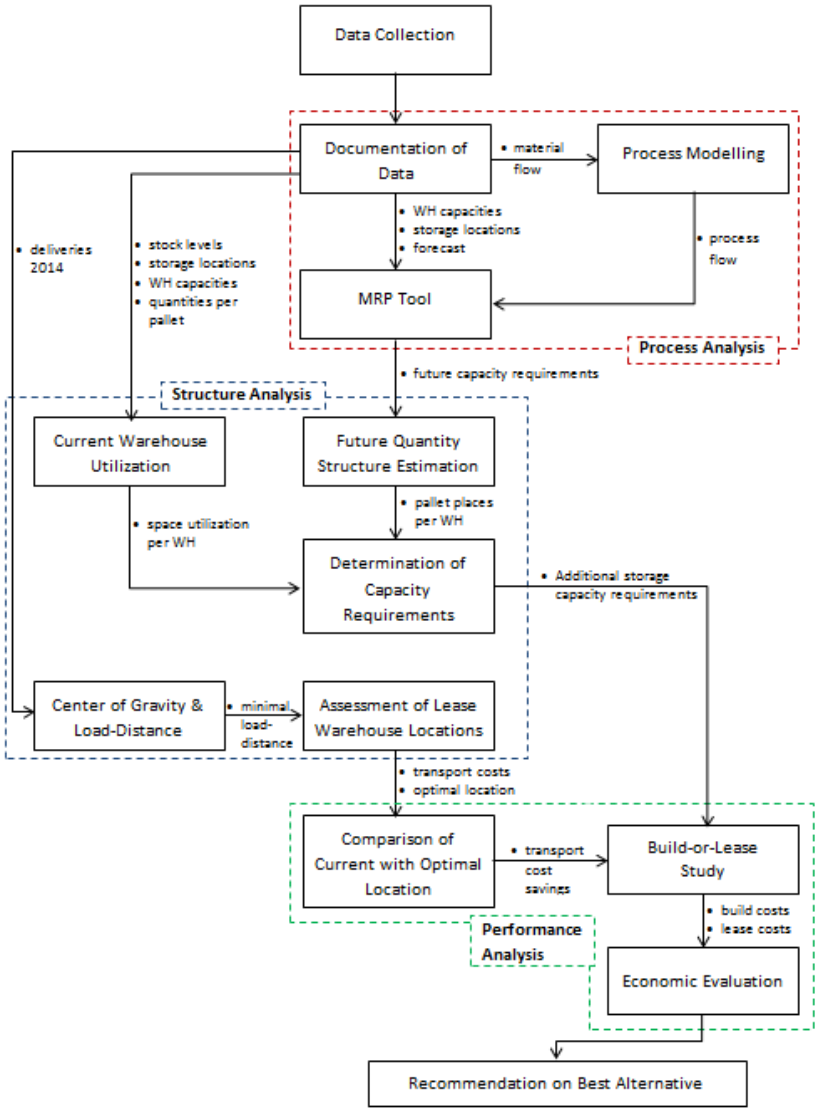

Fig. 2. Research framework

V. Key Performance Indicators

To track the progress of the analysis, measure outcomes at certain steps and ensure that requirements are met throughout the research, key performance indicators (KPIs) are defined. This ensures that processes can be improved and capacity requirements will be satisfied with lowest possible costs. TABLE II. provides an overview of the determined KPIs and their use.

TABLE II. Key Performance Indicators

Category	Key Performance Indicator	Area of application / Description
Capacities	Warehouse utilization	Determine additional capacities
Alternative selection	Annual Worth	Justify build or lease based on economic factors

VI. Determination of Future Capacity Requirements

Twelve WHs are located on the site. Each WH is dedicated to a certain type of products. For analysis purposes, the material flow from arrival of raw materials (RM) and packaging materials (PM) until loading of finished goods (FG) on the truck for delivery to customers is reproduced in a Microsoft Access database which is used as a MRP tool. The database accesses the bill of material and combines it with the forecast. The required amount of pallet places (PP) per WH defines future capacity

requirements and is calculated with MS Access. Future capacity requirements are the calculated average forecasted peak season 2015-2017. The peak season represents the three consecutive months in 2015 to 2017 that have the highest forecasted sum. By this means, the potentially highest future capacity requirements are determined and a worst case scenario is established. If a WH extension is necessary or not can be determined by contrasting the available storage capacity with future capacity requirements.

The transparent red rectangles in the background of the bars in Fig. 3 indicate the available capacity of the respective WH. From the bar chart it follows that especially WH 1 needs additional space. Also WH 12, WH 3 and WH 4 are forecasted to operate slightly beyond capacity. WH 2 would probably exceed the desired 85% WH utilization, but still could hold all pallets. WH utilization as one KPI is applied in order to determine additional capacities. It is set to 85% in order to ensure smooth WH operations.

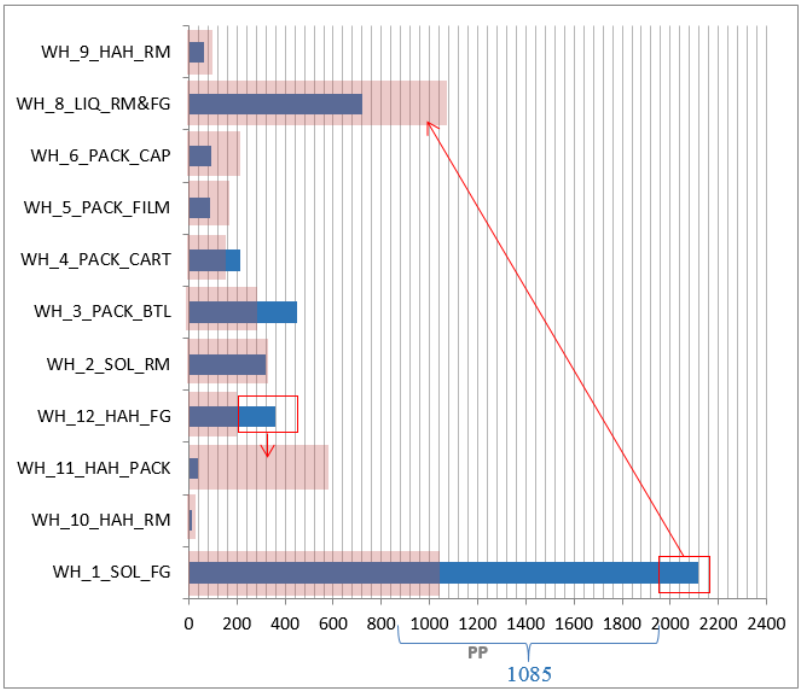

Fig. 3. Future capacity requirements

TABLE III. shows how many PP per WH can be occupied in order to still maintain a WH utilization of 85%. Additionally required PP constitute the difference between the maximum allowed number of occupied PP (85%) and the future capacity requirements. The critical WHs are emphasized with bold letters.

TABLE III. CALCULATED AVAILABLE AND REQUIRED STORAGE SPACE

WH ID	Total PP	85% WH utilization [PP]	Total future PP	Additionally required PP	Free PP
WH_1	1010	**859**	**2117**	**1258**	**-**
WH_2	324	**276**	**319**	**43**	**-**
WH_3	288	**245**	**450**	**205**	**-**
WH_4	156	**133**	**212**	**79**	**-**
WH_5	164	139	86	-	53
WH_6	216	183	92	-	91
WH_8	1050	892	718	-	174
WH_9	104	88	63	-	25
WH_10	36	30	11	-	19
WH_11	560	476	38	-	438
WH_12	200	**170**	**358**	**188**	**-**

WH 3 and WH 4 are for PM with a total requirement of 284 (205+79) additional PP. The PM WH 5, WH 6 and WH 11 have a total amount of 582 (53+91+438) available PP. This is more than sufficient to cover the peak requirements for all PM. So there is no need for additional storage space for PM.

WH 11 would still have 298 (582-284) of free PP. FG from WH 12 can also be stored in WH 11 because both WHs are dedicated to one type of product. It also makes sense since both WHs are right next to each other. Hence, the 188 PP required for WH 12 can be covered by WH 11.

Although utilization for WH 2 would exceed 85%, it is not necessary to take action since the WH still can hold all future pallets.

WH 8 could hold 173 additional PP which could cover a partial capacity demand for WH 1. Eventually, 1085 additional PP for WH 1 cannot be covered by existing WHs. Hence, a new WH capable of holding 1085 pallets for solid FG should be considered.

VII. Optimal Lease Warehouse Location

If a WH should be leased from a LSP, the best location for a new WH should be found first. This ensures that distances to the customers and thus transportation costs are minimized. Two conditions have to be considered before an optimal location can be determined:

- The existing WHs on the site should be kept
- Only one additional WH should be considered

Since the future freight demand or sales patterns are not known, the analyses are based on the sales distribution from the year 2014 only. The existing site with the twelve WHs is in Bien Hoa (Vietnam) und currently serves 361 customers who are spread across Vietnam. To simplify route planning and obtain an overview about the current situation, the 361 customers are consolidated in provinces. The sales distribution shows that 56% of the sales are generated in the Mekong area which consists of 13 provinces. Thus, the location alternatives can be narrowed down to this area. All other provinces across the country are not promising locations, as promising locations will be at or near concentrations of demand [4].

The center-of-gravity (CoG) technique is utilized in order to determine the optimal WH location. This is a heuristic approach for locating a WH. An optimal solution cannot be found this way. However, literature shows that the outcome of the CoG technique deviates only slightly from the optimal solution. Hence, this approach is justified and delivers adequate results. It should be noted that the determined optimal WH location is just a starting point that has potential for a new WH. Subjective factors (e.g. road conditions, availability of roads, law regulations, etc.) might reject the determined location.

Since the future freight demand is not known, the analysis is based on the sales distribution from the year 2014 only. Consequently, the results are only valid if the freight proportion of the sales remains more or less stable. Significant changes in the future freight distribution might result in another location to be the favorable one.

Fig. 4 shows the relative distances between the 13 provinces and Bien Hoa. The coordinates represent the geographic middle of each province and were determined with Google maps. Spreadsheet software was used to calculate and illustrate the coordinates of the optimal WH location. The origin of the diagram has the GPS coordinates 8.962440, 108.687493. The proposed location for a new WH is indicated by the red square and was calculated with the following equation:

$$\mathrm{x} = \frac{\sum_{i=1}^{n} x_i W_i}{\sum_{i=1}^{n} W_i}, \ \mathrm{y} = \frac{\sum_{i=1}^{n} y_i W_i}{\sum_{i=1}^{n} W_i} \qquad (1)$$

where
x, y = coordinates of the new facility at center of gravity
xi, yi = coordinates of existing facility i
Wi = annual weight shipped from facility

The resulting coordinates are x = 318 and y = 149.

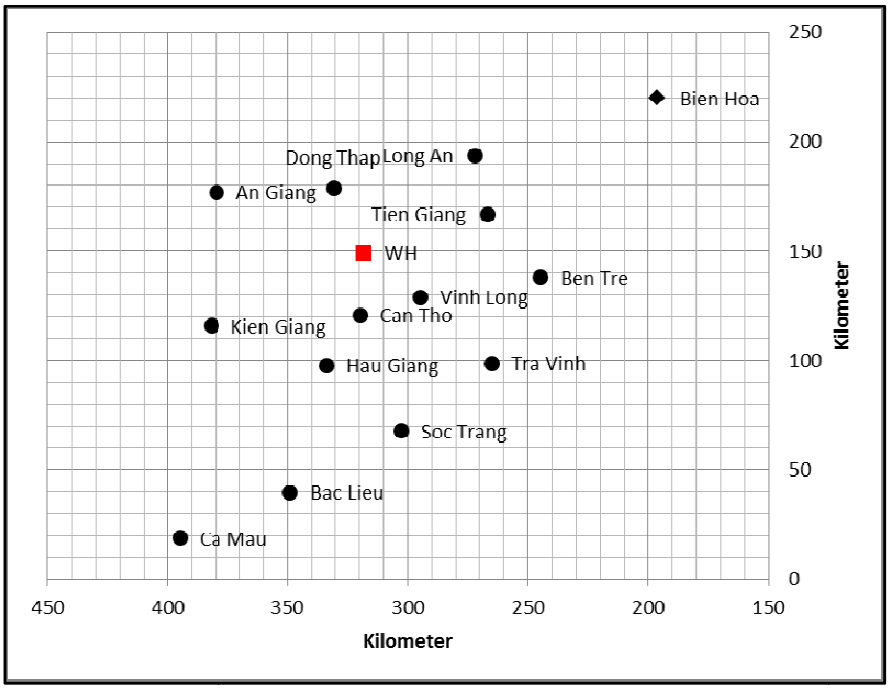

Fig. 4. Coordinate grid of the provinces in the Mekong area

Based on the CoG technique, the new WH should be located somewhere between the provinces Dong Thap and Vinh Long.

VIII. Economic Evaluation

The economic evaluation considers one lease and one build option. For the build option, the storage investment for building and operating a WH is estimated. The racking system is designed for 1085 PP, considers the pallet size 1400 mm x 1000 mm x 1800 mm (L x W x H) and a maximum pallet weight of 1,000 kg. There is sufficient land area available so that a new WH could be built on the site. The costs for leasing a WH in the determined optimal location are based on price lists from LSPs.

On the one hand, building a WH on the site is a strategic decision with a long-term commitment and relatively high initial costs compared to leasing. On the other hand, leasing a WH requires much less initial costs and provides flexibility, but results in higher annual operating costs (AOC). The economic evaluation reveals if it is more attractive to lease or build a new WH.

The expected lives of the two options are assumed to be significantly different from each other. That makes it difficult to compare both options in economic terms. Blank and Tarquin [1] suggest using annual worth (AW) analysis for this type of comparison. The AW value represents the equivalent uniform AW of all estimated cash flows during the life cycle of the alternative. The supply chain department stated 15.1% as current WACC (weighted annual cost of capital). This interest rate is used for the calculations. Both alternatives represent mutually exclusive cost alternatives and consider cash outflows only.

Since future estimates (e.g. expected life) are always incorrect to some extent, economic projections are usually inaccurate. To improve the chances of selecting the best alternative, a sensitivity analysis is conducted. The sensitivity analysis determines how AW is altered when the study period varies. With this approach only one parameter (life) at a time can be varied, and independence with other parameters is assumed. For example, the interest rate remains stable if the expected life varies. The AW value is especially sensitive to the estimated life or AOC of an alternative. The AOC are obtained from LSPs for the lease option and from the company for the build option. An arbitrary variation of AOC would result in random AW values which do not reflect the real situation. Therefore, the sensitivity of AW to life variation is evaluated. Fig. 5 depicts exemplarily the cash flow diagrams for both lease and build options. A1 represents the geometric gradient series of the AOC. A2 represents the annual costs that do not change. The sum of A1 and A2 is the total AOC.

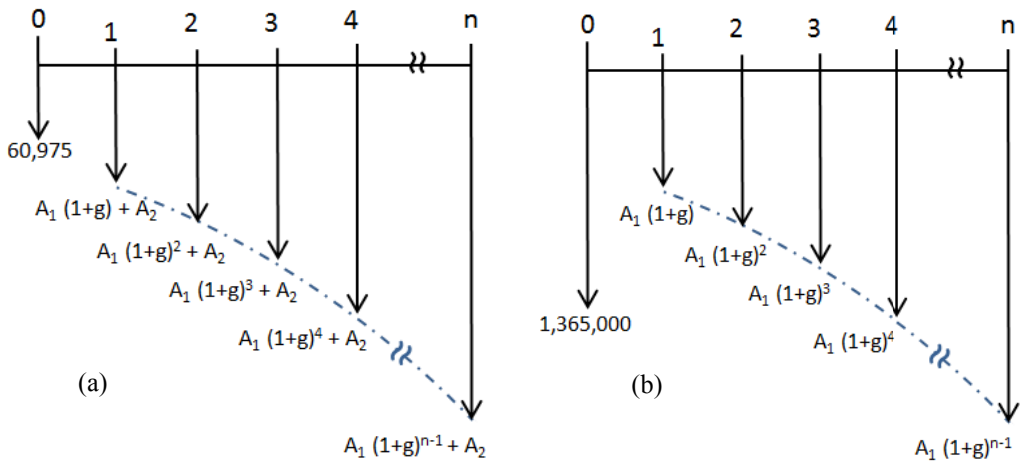

Fig. 5. Gradient cash outflow diagram for (a) lease and (b) build option

The selected range of values is lives (n) from 1 to 50 years. Fig. 6 shows the resulting plot of AW versus life. The AW values for both lease and build options can be obtained from the diagram for up to 50 years. For example, the AW for building a WH and an expected life of 20 years is 261,733 EUR. The AW for leasing a WH and an expected life of 5 years is 126,737 EUR.

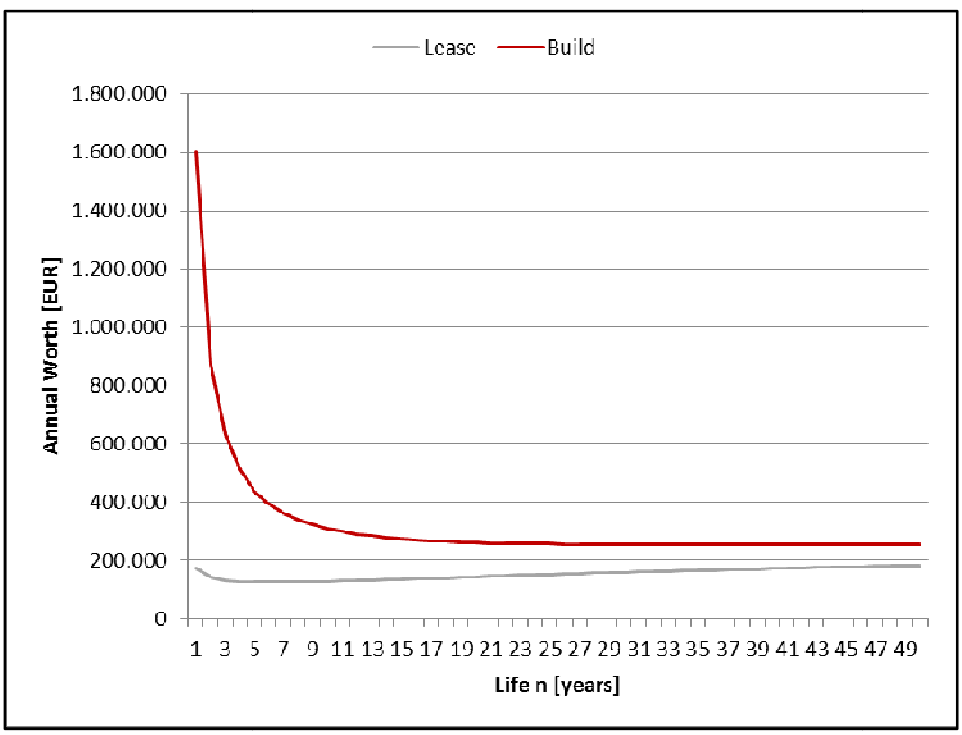

Fig. 6. AW sensitivity to life cycle

Each graph shows the annual cash outflow which is financially equal to all costs for the respective life. The diagram shows that the AW for building a WH on the site is quite sensitive if the chosen life cycle is up to about 10 years. If the life cycle is between 10 and 50 years, the AW value does not change much. It seems that the build alternative can never outperform the lease alternative (at least not in the next 50 years) since the AW values (which represent cost) are always higher.

In contrast, the lease alternative is not very sensitive to the chosen life and the AW is increasing with the life almost linearly. This stems from the comparably low initial costs and relatively high increasing AOC. In summary, the lease alternative is preferred over the build alternative no matter which life cycle is chosen.

IX. CONCLUSION

Increased production volumes resulted in high WH utilizations and storage space shortages so that products were shifted between WHs or stored at randomly available places. One WH was found to be the bottleneck since it operated significantly beyond available capacity. Future capacity requirements were determined based on the forecasts until 2017 under consideration of a desired WH utilization of 85%. An Access database was set up and used to calculate the overall future capacity requirements per WH. The database functions as a MRP tool which calculates the dependent demand from the independent demand (forecast). A worst-case scenario was established in order to ensure that the WHs can hold all future products. The evaluation of the available storage space and the forecast scenario revealed that 1085 additional PP are required in order to satisfy future storage capacity requirements. The objective to evaluate storage space requirements can be seen as achieved since the bottleneck in the system was determined and future storage space requirements were calculated.

An optimal WH location was determined by means of the heuristic CoG technique. The optimal location is supposed to serve 13 provinces only and has the potential to reduce annual transportation costs. The final recommendation favors the most economical alternative (least cost) which would be leasing a WH with 1085 PP at the optimal location. The objective to find the best alternative for a potential WH extension can also be seen as accomplished because leasing a WH at the optimal location constitutes the most economical solution with the potential to minimize transportation costs for the entire distribution system.

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