Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
*Young Researches and Scientist Paper / * Supervisor, Mentor*

INDUSTRIAL BUILDING LIFE CYCLE EXTENSION THROUGH CONCEPT OF MODULAR CONSTRUCTION

ZAHHAROV, R[oman] A[leksei]; BASHKITE, V[ictoria]; KARAULOVA, T[atjana]* & MIINA, A[leksandr]

Abstract: *As the global population grows and standards of living improve, there is an increasing stress on the world's limited resources. Thus engineers of present and future are already asked to use the earth's resources more efficiently and produce less waste, while at the same time satisfy an ever-increasing demand for goods and services. Green engineering of product life cycle emphasizes these and related issues. It is very important to consider every period of a product life cycle due to its use of energy (producing, running, maintaining, recycling, and disposing). This research describes how a complex product life cycle can be extended on the example of modular concept application in the industrial building construction.*
Key words: *Product life cycle, modular building.*

1. INTRODUCTION

Many manufacturing companies are changing their production philosophies from a traditional focus on the manufacturing of the physical product towards a focus on the life cycle of the physical product. As a result, more focus is now put on the use and end-of-life phases, including maintenance and remanufacturing (Sundin et al., 2005). The life cycle consists of all the inputs and outputs required from extraction to manufacturing to use, and finally to disposal.

Product EOL (End of Life) extension will be considered in this paper on the base of modular building constructions. Permanent modular construction is becoming more and more preferred construction delivery method due to inherent “green” construction methods employed, speed of delivery, and quality of construction, cost nature of modular construction delivery and flexibility of architectural design.

Mostly when we think about environment friendly constructions we think of buildings with solar panels and wind turbines, but that really is not enough to make for the need of our injured planet. Modular buildings manufacturers take into account this idea of constructing an eco-friendly house, from a scratch. Modular buildings manufacturers make use of eco-friendly techniques and recyclable resources in almost every step of the construction. These mobile buildings can be green in many ways.

The objective of the research is to extend product’s working life and to promote the product life cycle engineering in green way by using successful practices from different industrial areas.

2. PRODUCT LIFE CYCLE ENGINEERING

Life Cycle Engineering (LCE) is a process to develop specifications to meet a set of performance, cost and environmental requirements and goals that span the product, system, process and facility life cycle. The LCE process is an on-going, comprehensive examination with the goal of minimizing adverse environmental implications throughout the life cycle. LCE provides a means to:

- assess the environmental implications of alternatives;
- communicate the relationship between environmental implications and engineering requirements and specifications;
- identify improvement opportunities throughout the product life cycle.

Life cycle embodies material and energy use and waste throughout four conceptual stages:

- material production (material acquisition and processing);
- manufacturing and construction (involves the creation of parts and their assembly into the final products);
- use, support and maintenance (products are used, maintained and repaired);
- decommissioning, material recovery and disposal (retirement and disposal of products includes the decommissioning, disassembly, recovery of usable components, materials and energy, and the treatment and disposal of residual materials).

In order to obtain eco-efficiency, several life cycle engineering approaches can be applied, as for instance eco-design (or Design for Environment, DfE or DFE), Life cycle Assessment, Cleaner Production, among others (Daniela et al., 2009). Like pollution prevention, LCE can be considered as the judicious use of resources through source reduction, energy efficiency and material recovery. LCE considers environmental implications beyond facility gates, or beyond what applies “in-house,” such that environmental implications are not transferred to another facility within the life cycle. LCE offers a platform to apply improvement strategies and identify engineering activities in a manner more comprehensive than pollution prevention with respect to the life cycle. According to the LCE guidelines (Smith & Vigon, 2001), there are six categories of engineering activities that can be used in LCE as applied to product, system, process and facilities engineering.

Product’s life cycle can be represented through several stages (fig. 1):

- seller company should develop its product;
- product should be introduced to the public (introduction);
- product is sold in large quantities and producer starts to receive profit;
- during maturity period manufacturer should sell product until volumes are starting to fall;
- decline stage begins when there are only a few clients who are willing to pay for that product.

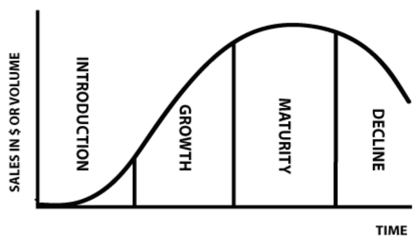

Fig. 1. Product life cycle can be also referred to service or business life cycle

Finally product is obsolete, demand is no longer exist – product life cycle is in disposal stage. Important tip is that producer should liquidate its product and promotion far before the sell cycle ends, approximately on the maximum point of the curve – at the end of maturity stage.

3. GREEN ASPECTS OF MODULAR BUILDING

In this paper we demonstrate case study of Pharmadule enterprise. Pharmadule is the world leading supplier of high-tech modular facilities for pharmaceutical and biotech industries. Pharmadule has production unit with controlled manufacturing environment in Estonia.

The advantages of modular buildings over traditional field-construction (on-site) approach can be seen from a variety of vantage points. One of the major advantages is predictability of construction costs and time schedule, as construction process takes place within a factory that operates as manufacturing unit, ensuring the building can be delivered on time and also on budget. Time overrun risks are also lower, as up to 80% (Pharmadule facts) of construction work is performed off-site in controlled manufacturing environment, while in a field construction, important factors such as local labour competence, reliability of local material suppliers or weather are beyond construction company control (Radulescu, 2010). Next step is transportation of individual elements of building (modules) to client site wherever that is located. After delivery, modules are either connected to the existing building or assembled into stand-alone modular facility. Either way off-site construction concept minimizes adverse impact within a neighbouring area, resulting in fewer disturbances. Modular approach also incorporates possibilities for future expansion allowing increasing buildings size as organisation demands for space grow. The expansion of modular buildings brings us to a second major advantage over conventional construction – relocation of the entire building or a part of it.

One of the greatest examples of industrial building expansion and relocation that took place in Sweden is described in this paper. The story has begun in 1992 when *Pharmadule* delivered laboratory to a client in Snäckviken, Södertälje. The project was a 1-storey building with one module on the second floor (8 modules in total). Later the same year 6 modules were additionally produced and added to form a complete second floor. In 1993 a third floor was added (another 7 modules), as per clients needs for expansion. In the late 90's *Pharmadule* was asked to quote for the 4th floor as client was considering further expansion. During the second half on the 90's client moved the entire building at least 2 times on the site in Snäckviken to allow access to conventional buildings and create space for conventional expansions (fig. 2). Sometime during the end of the 90's client decided to move the facility to site in Mölndal, in the outskirts of Gothenburg. The modules were transported to Mölndal and were now erected as 2 separate buildings. There client also did some repainting and put up new facade details to improve external look of the building. In 2006 it was time to change again. Client now wanted to move one of the buildings back to Södertälje and another to their site in Gärtuna. In 2007 one of the buildings was moved to Gärtuna, where 50m^2 of floor space were added. The remaining part in Mölndal was up for sale and about a year ago client was contacted by a person who was looking at buying modular building to reconstruct it into a sports gym.

Impressive is that fact, the client has moved entire building 2 times on the same site in Södertälje. Then it has been moved to Mölndal and separated it into two buildings and then one of those buildings has been moved back to Södertälje, but to another site. Such flexibility and efficient use of the assets is not possible a conventional building.

As modular facility has been relocated several times during period of two decades it is difficult to compile exact figures for new facility construction costs over such long period of time. In addition to cost fluctuations in construction industry, several up and downs in Swedish economy took place since 90's. Major currency fluctuations have happened for the period of 20 years as well. Therefore the average figures are used to assess possible stick-built facility costs if that would be newly built instead of modular facility relocation. For comparability of Pharmadule modular approach versus similar stick-built, only the cost of facility itself was taken into account. Additional costs, such as costs for furniture, equipment, land purchase, design fees, owner in-house engineering, landscaping, parking areas and major items outside facility's footprint were excluded.

Average module area is 60m^2, thus total facility area is 480m^2. According to average construction figures in Sweden for year 2005 similar stick-build building would cost approximately 1,27mlnEUR in today's currency. Accordingly, every time with modular facility relocation client direct savings on construction costs were at least 1mlnEUR. This is the great example where green solution is aligned with effective business planning through concept of modular buildings.

4. CONCLUSION

Green engineering design and manufacturing are affecting every aspect of our life. The green revolution will be even bigger than the Internet revolution is. Greening has already attracted a wide area of research topics and we believe will attract more and more. At the moment the most important thing what engineers can do is to provide the sustainable product life cycle strategy. Our goal is to promote the product life cycle engineering in green way by using successful practices from different industrial areas all over the world.

At current stage of our research of modular building green aspects and potential savings over stick-build approach, it is not possible to estimate construction material quantities that were saved via relocation of facility, and amounts of construction waste that was never produced because of reuse of existing modular building, due to limited amount of internal information available at Pharmadule. It is the next step in our research to estimate material and energy savings of current case study.

5. ACKNOWLEDGEMENTS

Hereby we would like to than European Social Fund’s Doctoral Studies and Internationalisation programme DoRa and company Pharmadule for provided case study and support with company internal facts.

6. REFERENCES

Daniela C.A.; Evelyn T., Americo Guelere Filho, Aldo R. Ometto, Henrique Rozenfeld (2009). Ecodesign methods focused on remanufacturing. *Journal of Cleaner Production*, Vol.18, No.1, January 2009, 21-31, ISSN: 09596526

Radulescu, R. (2010). Modular Buildings, Advantages of Portable and Modular Buildings Over Traditional Construction. *Available from:* http://www.articlesnatch.com/Article/Modular-Buildings--Advantages-of-Portable-And-Modular-Buildings-Over-Traditional-Construction-/1028531*Accessed: 2010-05-16*

Sundin, E.; Larsson, M. and Nielsen, A. (2005), Design for functional sales – a case studyof forklift trucks at BT industries, *Proceedings of EcoDesign-05*, pp. 12-14, ISBN**:** 1-4244-0081-3, Tokyo, December 2005

Smith C.;Vigon, B.(2001). Life Cycle Engineering Guidelines, Battelle Columbus Laboratories, pp. 8-12

*** (2003) http://www.arundelstreet.com -Business Life Cycle, Arundel Street Consulting, Inc, *Accessed: 2010-06-02*