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Mika Heinävaara

LEAN APPLICATIONS IN SHOP FLOOR LAYOUT DESIGN

TURUN AMMATTIKORKEAKOULU
TURKU UNIVERSITY OF APPLIED SCIENCES

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Instructors: Janne Roslöf, D.Sc. Marja-Leena Suomi, Lic.Sc.

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The purpose of this study was to plan, design and execute a new layout at the Sanmina-SCI factory in Salo. This corporation commenced a global lean development project in 2008 which served as a practical entry point for the study, as there was a necessity for reorganization, since its current layout is outdated and, nor is relevant as a result of changes in technology and products.

The objective of the project was to eliminate wasteful space and thereby fixed costs. Further, ancillary objectives were a more effective and logical layout with e.g. a better flow of materials, more robust manufacture by repositioning of functions and machinery, and an increased focus on value added activities. Further, the new layout was planned to be concomitant with flexibility for any future changes in machinery, products, volume etc.

Lean principles and methods were utilized in this study and accomplished through layout and should support further improvements at the Salo plant. Personnel involved there also represented a valuable source of experience and practical skills required. The future state layout was considered as a starting point and foundation for further development. As such, this project provided a practical rehearsal for a specific team to familiarize itself with lean theories and methods. Overall, this project was primarily focused on a pragmatic operation, rather than pure scientific research. However, theoretical aspects have not been overlooked and a wider perspective to the subject has been pursued by touching on basic significant historical aspects, too.

The thesis includes two case studies which will serve to enlighten the challenges which contract manufacturers face in the modern and global business environment. The result of this study is an accomplished future state layout with better flexibility to meet future business challenges.

KEYWORDS:

lean, close couple, material flow, layout, value stream

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LEAN-SOVELLUKSET TUOTANTOTILOJEN LAYOUTSUUNNITTELUSSA

Opinnäytetyön tarkoituksena oli suunnitella ja toteuttaa uusi layout Sanmina-SCI:n Salon yksikössä. Yrityksessä aloitettiin globaali kehitysprojekti, jonka tarkoituksena on siirtyä asteittain lean-tuotantoon kaikissa yhtiön mekaniikkaa valmistavissa yksiköissä. Uusi layout on joka tapauksessa välttämätön Salon yksikössä johtuen viime vuosina tapahtuneista muutoksista tuotantotekniikassa ja tuotteissa.

Projektin tavoitteena oli vähentää tuottamatonta tilaa ja siten alentaa kiinteitä kustannuksia. Muita tavoitteita olivat mm. parantaa materiaalien virtausta tuotannossa, keskittää ja selkiinnyttää toimintoja koneiden paremmalla sijoittelulla ja huomioida paremmin lisäarvoa tuottavat toiminnot. Lisäksi pyrittiin mahdollisimman joustaviin ja helposti muunneltaviin ratkaisuihin, jos ja kun muutostarpeita tulee.

Työssä on pyritty toteuttamaan lean-periaatteita ja menetelmiä sekä luomaan edellytykset jatkuvan parantamisen ja kehityksen periaatteille. Projektiin on osallistunut henkilöitä, joiden osaaminen ja käytännön kokemus on ollut välttämätöntä projektin toteuttamisessa. Projektiryhmän jäsenet ovat prosessin myötä oppineet leanin teoriaa ja käytännön menetelmiä. Yleisesti projekti on sisältänyt enemmän käytännön toimintaa kuin tieteellistä tutkimusta. Teoreettista pohdintaa ei ole kuitenkaan sivuutettu ja perspektiiviä on pyritty laajentamaan tarkastelemalla aiheeseen liittyvää historiaa.

Opinnäyte sisältää kaksi tapaustutkimusta ja niiden toteuttamisessa on hyödynnetty lean-periaatteita. Tapaukset toimivat lukijalle myös esimerkkeinä niistä haasteista, joita sopimusvalmistajat tänä päivänä globaalissa toimintaympäristössä kohtaavat. Projektin säästötavoitteet täyttyivät ja tuloksena oli uusi layout, joka antaa yritykselle paremmat valmiudet kohdata muutokset tulevaisuudessa.

ASIASANAT:

lean, close couple, material flow, layout, value stream

FOREWORD

This thesis is another milestone, again, in my long journey as an adult student. It could also be the last too! Although, as it is advised, ‘never say never’, since this train has now kept on rollin’ 22 years so far....

Thus, for this particular stage of the journey, I wish to extend my thanks to the following people without whom (etc.):

First, naturally, Sanmina-SCI and my supervisor Mr. Johnny Nyman, for providing this opportunity; my instructors Janne Roslöf D.Sc. and Marja-Leena Suomi Lic.Sc., for their support and supervision during this process; my colleagues and fellow employees who provided their experience and knowledge to utilize, especially Mr. Harri Kuittinen for the material and collaboration and Mr. Ron Brown for the drive and challenge to complete this task.

For a work such as this, I must also express my gratitude to friends and colleagues, Juha Hoppela M.Sc. for his engineering discussions, Timo Peuhkuri D.Soc.Sc. for a more non-engineering approach, and with special thanks to Paul Whybrow B.A. (Law) for his indefatigable tenacity in his logical and ‘lean’ proofing: indeed for all their overall kind encouragement and especially ‘out-of-the-box’ support, to all, ‘Cheers mates’!

Finally, it is also very important to acknowledge my gratefulness to my children, Vilja, Johannes and Otava for their patience throughout in tolerating Daddy often having to be elsewhere, and most especially, my most loving partner, Kirsi, not only supporting me throughout, of course, but for being the original instigator for this all, and then pushing me through the challenging times to complete it.

04/12/2010, Littoinen

Mika Heinävaara

CONTENTS

1 Introduction

For any industry and/or business, the drive and development towards better performance, is not only self-evident, but essential. The globalizing economy and the rise of new economies over the last decades have begun a new era of globalisation. Integration, telecommunication, faster transportation etc. have made information and people increasingly mobile. Knowledge has become available for anyone at any time and everywhere. However, the efficient and effective targeting of the required efforts, is far more challenging. Companies have attempted to find solutions to survive in this ever changing business environment being in a constant state of relentless competition.

This thesis shall deal with a layout design and execution for e.g. a one piece flow production which forms a natural continuum to my prior Bachelor's thesis theme - "Stock-material control planning for fan manufacture process" (pub. 2004) - and all prior similar works. It is a result of the efforts of much teamwork, whose members, although largely novices when the project started, nevertheless between them had over one hundred years of experience in the industry, since the development of processes especially requires all the available know-how for success, ideas, methods, technology etc. which have been discussed and specified in different forums and meetings from the experience and knowledge of the participants.

The thesis has two objectives: in main, to obtain a new practical layout yielding area savings solution, and to acquire practical skills for the future projects to come. Secondary, are the case studies undertaken which can be considered as a practical rehearsals of lean methods, an exercise in how lean applications work and what can be achieved with them.

The history of lean is discussed in chapter three, but some introductory notes here are appropriate. So termed "Lean" production and management is an American version of the Toyota Production System (TPS), which is one of the lean approaches most successful implementations. The Toyota Motor Company is the world's largest car manufacturer and has constantly developed its production system in Japan, from 1950, and which has thereby come to be latterly known as “Lean Production” to the rest of the world [1].

TPS itself is strongly based on both Japanese society and culture and is implemented into the enterprise and hierarchy throughout. It has, for example, been integrated into all aspects of a business, from recruitment and design up to the end of a product’s life. Conversely, more characteristic to Western countries, development resources are often allocated to products rather than processes. As such, the nature and approach of each is marginally different, yet nevertheless, both are intended to improve matters. In comparison to the American approach, which is more scientific, the European and Japanese is far more pragmatic [2].

Thus, even though the approaches and applications in Japan, America or in Europe or even in different countries will differ slightly, the overall objective can be adjudged to be same in each case elimination of waste, in this work viz. the elimination of wasteful space and the creation of a practical layout, with minimal risk to business opportunities, and associated preparation for future changes and the challenges these give rise to, as they occur.

Arguably, much hype can be said to be involved in lean; thus, before commencing on an appraisal of ‘Lean’ methodology and practises, since much, if not all, has already developed through improvement, it would, of course, be disingenuous and perhaps even disrespectful to previous generations, to proceed as though nothing had been achieved or done before, or is ongoing; that is: naturally, ‘lean’ approaches have undoubtedly occurred before, yet often without specific reference to, or knowledge of it.

Thereby, ultimately, it can be reasoned that the ‘lean’ approach is largely only ‘common sense’, in the arrangement, ordering and solutions to problems and then establishment of new procedures, and which, if already present, indicates to some extent that lean already exists - or at least has the potential to be manifested.

Lean is often introduced as an almost savior type of system intended to provide solutions to all issues in management, purchasing, production etc. with the expectation of rapid improvement. However, it is notable that the person often considered as the father of TPS, Taichii Ohno, in practice spent all his life developing the system.

Naturally the results can be remarkable and today implementers need not start from scratch, as it were, as he did. The current greatest challenge probably thus becomes the establishment and maintenance of procedures to continuously improve, yet throughout, still probe and question them [2].

Thus, although its ideas and practices had been in operation earlier, one attempt to replace an existing production system or model and implement a so known ‘Lean’ manufacturing process, was launched in the summer of 2008 by the senior management of the Technology Components Group. This plan was considerably ambitious and included objectives such as “transforming one factory in six months”. [3.]

The transformation process began in the Guadalajara enclosure unit in Mexico and then spread to the North-American and China units. However, rapid and significant changes in the business environment, together with economic recession at the end of 2008, resulted in changes to the plans and many of the planned operations were postponed.

At present, the company of the case study fortunately has the resources and experienced personnel to assist towards the types of projects discussed herein, and with the commitment of senior management, timing is arguably, ideal. However, prevailing economic conditions remain a threat and by which, economic support may thus become compromised, it remains a corporative initiative. Thereby, to put this approach (and research) into practice, is only a matter of corporate policy choice. Long term commitment in future success and growth are the keys for success. However, several processes and products must be explored in the forthcoming years to obtain better practices.

N.B. Lean manufacturing is often mentioned together with the term ‘Six Sigma’, a specific business management strategy originally developed by Motorola, Inc. [4]. However this thesis shall only concentrate on the layout planning and reconstruction on a specific practical level, and therefore focus on the creation of a functional and shop-floor space saving solution for this author’s employer current facilities. As such, Six Sigma is not covered in this work.

2 Sanmina-SCI (SSCI) as a contract manufacturer

The electronics industry had reached its highest market peak during 2007-08, until the slowdown during the recession of 2008 which resulted in SSCI forced to close units in Sweden in 2008 and then in Canada in 2009. Generally, the whole industry has been in decline throughout this new millennium decade. Despite several good years for revenues and profit, shareholder value had not been similarly created. Diagram figure 1 shows the trend of the stock value development of SSCI during the last ten years. Flextronics and Jabil, the major competitors of that period, are shown in figures 2 and 3.

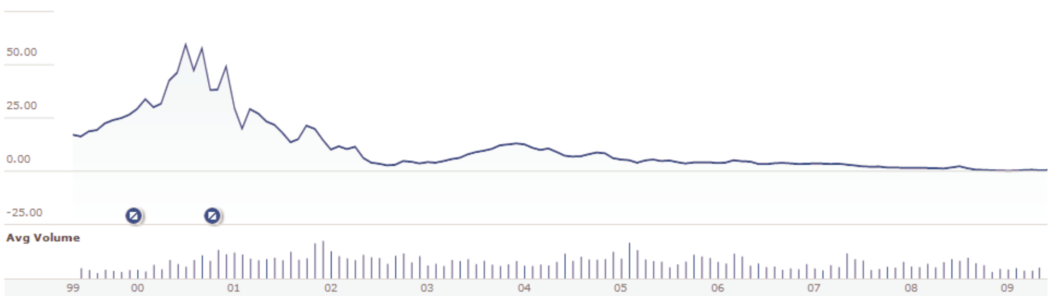


Figure 1. Sanmina-SCI stock value development 1999-2009.

Figure 2. Flextronics stock value development 1999-2009.

Figure 3. Jabil stock value development 1999-2009.

The Recession has been rapid but fortunately, analysts predict some recovery by the end of 2010. This progress is expected to be slow, but companies which are prepared to grow will likely succeed [5]. Mergers and consolidation are also expected, as customers appear to concentrate their purchases from fewer suppliers.

SSCI is one of the largest and leading companies in the electronics contract manufacturing business and is located in over 40 places on four continents. At the end of fiscal year 2008, it employed c. 45000 and total revenue was $7.2 billion [6]. Its main business is EMS-business (Electronic Manufacturing Services) which includes e.g. PCB's, backplanes and cable assemblies, enclosures and optical solutions [7].

2.1 Enclosures

Enclosure units are the mechanics manufacturers. Since 2001 when Sanmina and SCI merged and SSCI was founded in its present form, the number of the units has continuously decreased including closure of the enclosure unit in Uusikaupunki, Finland. By June 2009 there were seven enclosure units, two in USA, one in Mexico, two in China and two in Europe. Although each unit is very different in size, products and customers, sheet metal processing is common to all of them.

Increasing competition has directed the companies to provide even more service for their customers for their products. A manufacturer can provide valuable fabrication related knowledge for their customers. Further enclosures are increasingly involved in the early phases when products are developed. A trend which has become increasingly common during the recent years, as companies have outsourced their R & D functions. Toyota and Honda have succeeded in this in North-America, too - where American car manufacturers have failed - when they have provided their knowledge to suppliers to achieve better quality and price for their components. [8.]

2.2 Salo unit

The Salo unit had a long history before SSCI, as a mechanics fabrication department of the Salora Television factory in the 1960s [9]. Salora was founded in 1928, first as Radioliike Nordell & Koskinen (Salora Oy 1945), bought by Nokia in 1983, then sold to Swedish Segerström & Svensson in 1993 [10]. Sanmina bought S & S 2001 at which time the Salo unit became a part of the current SSCI [11].

Approximately 115 are employed at the plant. In the fiscal year 2009, turnover was $25 million, and is budgeted at $19 million for 2010 [10]. Its main markets and customers are in Europe, particularly Sweden. Its premises consist of a two different buildings and an additional warehouse, which is physically located inside another, all leased from different landlords.

The Salo unit has met a remarkable change in its product portfolio and manufacturing technology. At the beginning of 2000, its main technologies were progressive and stage stamping, and had a tool room with 20 highly skilled toolmakers and fitters. More than half of the production was small metal parts (small mechanics) for mobile phones. Its largest customer was Nokia Mobile Phones in Salo (in fact directly opposite on the other side of the street). Thus as Nokia expanded its operations abroad, as a consequence domestic demand decreased along with the unit number of the suppliers, so that by the close of 2005, mobile phones related small mechanics had practically disappeared.

As a consequence of this, the number of presses had to be decreased and half of the presses were removed, and small mechanics were replaced with new assemblies such as subracks and metal parts for the telecoms industry. The size of the products increased remarkably while, correspondingly, batch sizes decreased. Presses were gradually replaced with more flexible turret punching machines and press brakes. As a consequence of this restructuring, machines were moved to Salo from the other units. [12.]

In 2008, SSCI closed down its enclosure unit in Forserum, Sweden, and the existing production moved to Salo and Miskolc, Hungary, where larger assemblies were produced. This doubled the assembly work and turnover, too in Salo. To secure the capacity and flexibility, one turret press was also moved to Salo.

This transition was accomplished in just a few weeks with some empty spaces fortunately available in the Salo facilities, thus since time and resources were limited any particular layout or transfer plan did not exist, so that tables, tools and workers were randomly allocated into the unused areas. Production continued until the beginning of summer 2009, when customer demand relocated the main part of the production transferred to China.

As such, the premises layout had to be reorganized, although it became clear that such tasks could not be managed properly in the future. It also revealed the lack of reasonable material flow and functional sequences. Naturally there were many reasons which complicated the issue, of which the out-of-date layout was one.

3 The “Lean” concept, background and origin

The nature of lean is a continuous and never ending process development with a strong focus onto shop-floor functions [13]. As such, of course, a final and optimal (perfect) solution can never finally exist, only the continuous strive for improvement. Solutions and decisions are largely arrived at through comparisons between lean theories and then through its application in practices and experiences. Consequently, it is not self-evident and thus has many rivals, though there is far more supportive literature available for it, than critiques, and even though some researchers now investigate a so called ‘post-lean’ approach and idea, at present lean has not been completely rejected and its benefits still recognized. [13.]

Copious (bordering on excessive, perhaps!) references are available e.g. a “Lean Consulting” search on the internet will demonstrate, providing more than six million sites: thereby the assumption is necessary that not all will be productive to consult nor all related books. Moreover, further articles, studies and magazines are valuable material of which, as noted, many are available via the internet, and which is also a very efficient provider of current status updated economic information, too.

Further, interviews, courses and discussions with experts and colleagues should not be underrated as references, either. Hence, consultation in the name of lean is a very lucrative business. At minimum, considerable knowledge is available, and perhaps the task here is to attempt to select the best which likely fit the task presented to this thesis. However, practical experience and knowledge is indispensable. Thus, communication is paramount when collecting and sharing information.

Since many of the practices of the approach were set in place long ago, it is germane to briefly review its historical aspect, so to appreciate the contexts of such events along with their consequences, too.

3.1 References

To understand modern industrial work and production, familiarity with Henry Ford, the father of mass production, is essential. He wrote “My Life and Work”, in which he explained the development of the company and his methods. Even though his skills in management perhaps no longer match the modern understanding of leadership, in contrast, his approach and abilities in production demonstrate that Ford still remains remarkably, innovatively ahead of his time, and although lean professionals prefer to differentiate between mass and lean production, Ford's influence is well seen and acknowledged in all the lean literature, and the two concepts have more in common than any disjunctive features.

For the management aspect, it was Frederick Taylor who introduced purpose of management, which Ford otherwise paid little attention to (probably because his own method was somewhat akin to benign dictatorship). Nevertheless, when considering working conditions or any human aspects, neither displayed much concern towards, particularly when compared to a present-day viewpoints; but allowing for the different considerations of a century ago, Taylor's time studies remain the foundation of the standard work and e.g. the price determination of products.

Of the subsequent literature, the most significant include: "The Machine That Changed The World" by Womack, Jones and Roos as one of the most important works on the subject, which provides a good basic understanding of its theory and terminology [1]. "The Toyota Way Fieldbook" by Liker and Meier, is a more practical work which contains many examples with practical tips [14]. "Lean Roadmap" by Howard M. Thomes [15], provides ideas for material issues, and "The Federation of Finnish Technology Industries" has also published helpful material where lean projects have been undertaken and executed in Finnish companies [16].

Of these, Terry Wallace and Christian Berggren have studied alternative solutions in the Swedish automotive industry, and Berggren especially criticizes "The Machine.. " vigorously, for as abovementioned, lean is not a self-evident solution and other options have been suggested and put forward, too, such as cellular manufacturing or fractal factory.

'Mass customization' was a term coined by Stan Davis in his book 'Future Perfect' and then further developed by Joseph Pine [16]. Thus, mass customization and Lean production have a clear linkage, as it is considered that before mass customization, lean methods must have been implemented into the manufacturing processes. Mass customization is mass production with a wide variation capability, and modular configurations are often utilized. [16.]

“Lean production is “lean” because it uses less of everything compared with mass production”, was explained by Womack in “The Machine..”. In fact, the term “lean” was only first coined by John Krafcik in 1988, an engineer at the NUMMI, Toyota - GM joint venture [1].

However, as indicated above, the roots of lean production or TPS cannot be considered without reference to Henry Ford and his own Ford Motor Company contribution to the automotive industry, his innovations and insights and technological development in industrial manufacturing in general.

3.2 Ford

Many of the driving factors of lean have their origin at Ford’s factories, though the terms used then, might have been different. Waste, continuous improvement, close coupling, value stream, sequences and many others were in place and operation at the Highland Park and Rouge manufacture premises.

In the early history of the automobile, a car itself was originally an exclusive symbol of status and luxury. But Ford wanted to manufacture a cheap and practical car for the common man and rather for functional use. He realized that the current craftsmanship involved was a far too expensive way to produce cars, so created a standard car that was easy to repair with interchangeable parts. This new product was the famed Model T, the first real industrial success story.

However, Ford was an inventor and experimenter. Before the Model T’s success he had already previously designed eight models, all of which had been in production, too. He tested different motors, clutches, transmissions, drives etc. and the best solutions were transferred into the Model T, so that every detail and feature had been fully tested in practice. Therefore, Ford had no doubt about its eventual success. [17.]

Ford’s continuous improvements reduced the cycle time at the chassis assembly from 12,5 hours down to just 1,5 (93 minutes). Although more driven towards productivity improvement and cost reduction over quality, still his quality was already better than

Ford’s rivals. Persistent efforts to reduce waste in production resulted in 170 000 cars produced in 1913 [15]. For the significance of this, compared with Toyota which only achieved the same figures at the beginning of the 1960s [18].

Ford was very much a self-educated ‘engineer’ and highly interested in technology. As a result of the success and increase in demand for his model –T, Ford had to find a way to produce even more cars. He created a line production which he improved by developing a composition of workers and line, along with better precision of the parts assembled. At Highland Park, Ford had a very unique assembly line he called “flow production”, probably the first version of the single piece flow. The real mass production system was introduced at Rouge. [1.]

Thus, it is fair to credit Ford with the creation and development and the foundation of modern mass production, which soon became a common technique in all auto plants in USA and Europe, to the most modern of technologies which are still in use, especially in an assembling industry, although now as more sophisticated versions of Ford’s factories.

Indeed, today the Ford Motor Company remains one of the world’s largest car manufacturers and incidentally the Ford family remains still the major shareholder of the company.

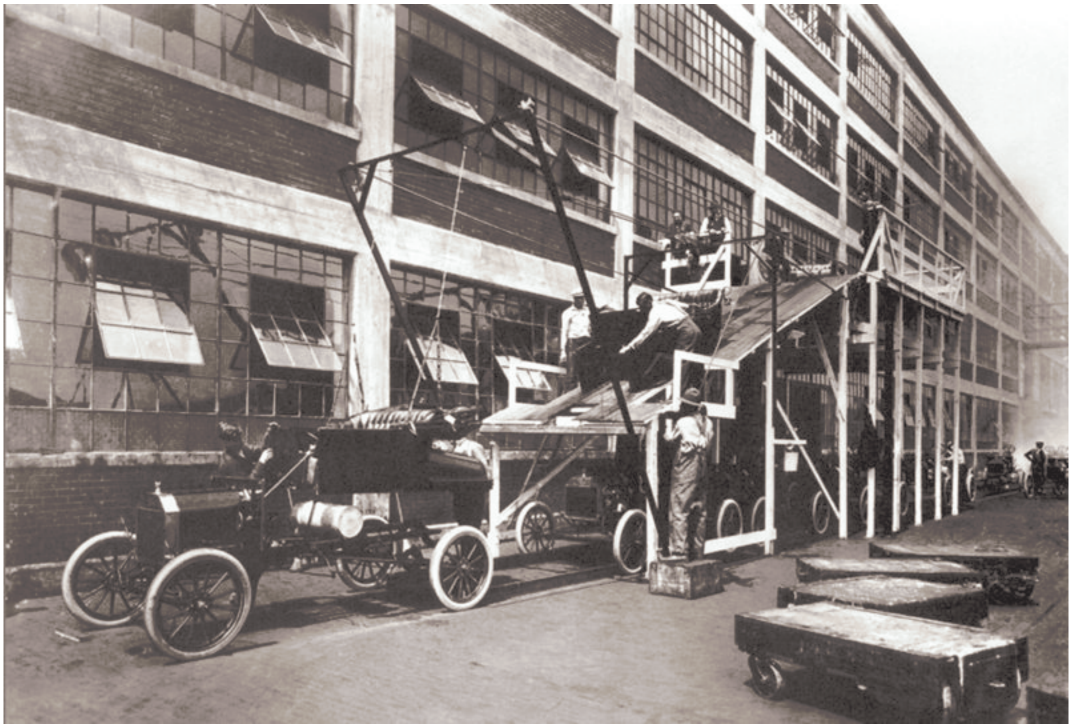


Figure 4. Ford assembly line in 1913.

3.3 Toyota

Sakichi Toyoda was Ford's Japanese contemporary, although he began in a different business. Born in the countryside, the handloom was very common in most homes, but Sakichi often found many malfunctional and tried to improve them. In 1891 he patented his own version, but soon found more interesting apparatus in a weaving machine. His early versions were cheaper and better than German or French rivals, but not yet that good as British ones. His relentless work and strive for quality finally produced a new invention, the automatic G-type weaving machine with numerous features that did not previously exists. [18.]

Similar to Ford, Sakichi was also a self-educated man, but his son, Kiichiro was a trained engineer and more interested in cars, and it was under his control that Toyota concentrated into the automotive manufacturing industry in late Thirties. Kiichiro coined the term "just in time", as a result of his studies on Ford's system in operation. His scientific approach to the technical problems finally resulted the first engine ever manufactured by Toyota. Though a copy of the Chevrolet model, the Toyota version was enhanced in many ways. The first automobile, the model A1 was manufactured in 1935, more or less a copy of a Chrysler of the time [18].

The history of Toyota became a sequence of ups and downs through the Second World War, the American occupation and the Korean war. The quality of its cars was poor by 1950, and production was only 40 cars per day as against Ford's 2000. Succeeding Kiichiro, his cousin Eiji Toyoda became head of the company and concentrated on quality issues and the search for reliable suppliers. Soon replaced by Ishida Taizo, now from outside the family, the real power in the company could be said to be in the hands of its chief engineer, Taiichi Ohno. [18.]

3.4 Taiichi Ohno, Shigeo Shingo and Toyota Production System

Ohno was a very production oriented engineer and emphasized methods and standardized work. Although well aware of the Ford techniques and methods, he also realized that the markets of Japan were totally different, since Toyota had to find a way to produce a high variety of products but still with the methods of the mass production. As such, Ford's methods required considerable fine tuning.

On a visit to a supermarket, Ohno was struck with how everything necessary was available and customers did not need to hoard products, and noted how supermarkets supplied merchandise in a simple, efficient and timely manner [19]. Indeed, for anyone interested in lean, Ohno's simple observation can similarly be made by walking into any supermarket: a cursory visit to some fast food establishment to exercise Ohno's method and "stand in the circle" to observe the process he originally saw [14].

Consequently, it is Ohno who is often considered to be the father of the TPS; although in reality, the success of the system is the result of his collaboration with Shigeo Shingo. When Ohno made his career at Toyota, Shingo was an international consultant who collaborated with many large companies, including Toyota. Shingo was well known by his contribution to improve setup times, quality control and finalizing the "Just In Time" system with Ohno [14]. A recognized Finnish consultant, Pekka K.J. Harju, ranks his literary output as more important than e.g. Liker's Toyota studies.

The seminal work "The Machine That Changed The World" is a five-year study of the Japanese automobile manufacturing, which was made at the Massachusetts Institute of Technology (MIT). Ford’s contribution is well recognized as well as the General Motor’s later influence, as being the world’s biggest automobile manufacturer for 76 years [20]. Nevertheless the main interest is still directed to Toyota and its production system, TPS, as primarily developed by Ohno and Shingo, and which is considered as pre-eminent, since Ford and GM are considered as the mass producers but which likely have little future, if they are unable to assimilate lean production methods and methodology.

In general, a continuum from Ford up to the Toyota is apparent through Frederick Taylor’s time – and – motion studies and idea of the division of labor which Ford was very likely well aware of, as it was an important principle when Ford was striving for better efficiency. Taylor also established that the scientific management and the cooperation of management and labor was also an important factor of the standard work that Ohno vigorously emphasized [21].

Thus, Ford and Ohno remain ‘lean’s most significant figures, and their influence over the concept’s development can never be disregarded. However, naturally, from when the introduction of the vehicle was new to society, its demand has spurred the industry to develop, which, unlike shipping for comparison, has developed apace to date, as manufacturer’s have been compelled to continuously improve performance as competition increased.

Further, as outlined, the ‘lean’ approach has its origins in automotive manufacturing and particularly at the Toyota Motor Company, via which it has also expanded around the world to North-America and Europe, and it is not coincidental that this origin and development has occurred particularly for assembly. For this, there are distinctive reasons, as are set out in the next chapter.

4 Lean aspects in layout planning

The automotive assembly industry utilizes the largest assembling operations in the world. In MIT's study, more than ninety plants were visited and investigated, representing almost half of the assembly capacity of the entire world at that time [1]. Plants are vast and thousands are employed. Massive conveyers are needed to move vehicles through the assembly and more than 10,000 parts are involved in the assembly of the average car. Therefore any reduction in space, inventory or cycle-times – even the minor ones - will provide returns with significant savings.

One of the determinants in lean, is the standard. The standards at work, methods and parts are the basis for any improvement. Indeed, the completed car itself is even largely a standard, since although body designs will vary, around the world the fabrication techniques are remarkably similar and the most common method in manufacturing is a line production. Similar, or even the same, parts are used in different models [1]. As a consequence of outsourcing along with collaboration, even different manufacturers may use the same parts, to achieve the benefits of economies of scale.

However, the design of a vehicle is a very complex task and requires know-how from many areas. Facilities and equipment are expected to be utilized for a long time. In this way, design is very much related to fabrication. It is also a crucial phase in car manufacture, since any failures in design will simply recur later in production. In a worst-case scenario, a problem may go undetected, perhaps even ignored, and ultimately suffered by the customer e.g. consider Toyota in 2009, when 4,3 million cars had to be recalled for a malfunctioning accelerator pedal - even suspected to be a cause of some fatal accidents. Its manufacturing plant was stopped at a cost of over a billion dollars per month [22].

4.1 Approach

However, the purpose of this thesis is not to discuss lean nor present its theory entirely, but rather to find solutions that the lean approach can provide for layout planning. As such, the main observations herein are for practical issues to enable the creation of long term solutions. Experiences from Guadalajara and Miskolc convinced the project team that such streamlined solutions implemented in those units, were not feasible in Salo, except in certain areas as explained in the relevant case studies. The main goal was an overall solution with acceptable costs. Options for “kanban” solutions in future were also requested, although it is a next step after layout is accomplished. Where applicable, selected principles and methods are discussed in this chapter. However, it is first important to explain the purpose of certain concepts, which in point of fact, are rather simple to comprehend.

A core fundamental principle of lean is simply waste reduction throughout all work activities. As Taiichi Ohno described, “it is question of the time line from the moment the customer gives us an order to the point when we collect the money” [14]. The reduction of the time line – in manufacturing, the lead time - is achieved by the elimination of waste. The most significant way to achieve this, is to create a value stream, which is typically in the form of a production line. In general there are three common types of layouts: functional or cellular production, and production line.

4.2 Types of layout

In the functional layout, machines are grouped by technology, and a traditional machine workshop will usually be so functionally organized. Functional production is flexible and easy to construct. It is less vulnerable to disruption, and capacity can easily be increased, but its disadvantages include usually large WIP (Work in Progress) and low efficiency. Arising from multiple schedule points and long lead times involved, production management can be difficult and challenging.

Functional production is driven by machine use effectiveness, which usually results in large batches and WIP. Contrary wise in lean production, batches are minimized to enable flow and visual control i.e. machines are designated and located by operational sequences. However, in a functional system, machines are often in general use and therefore cannot be grouped as a proper value stream requires.

The production line or flow line layout is usually designated for one or several similar products e.g. as in car manufacture. It is effective and simple way to manage as it is usually paced. As such, the factual yield becomes calculable in advance. WIP is minimized from the continuous flow. However, such lines are often expensive and difficult to construct. Any disruption may halt the whole line and capacity is difficult to increase. To achieve reductions in the unit costs and make investments profitable, lines usually require mass production. Thereby, lean methods are particularly implemented into line production solutions. [23.]

However, due to the pace involved, line system operation is usually repetitive and thereby stressful and with respect to efficiency, resultant high intensity of concentration together with short cycle times, can give rise to increased health risks e.g. particularly cumulative trauma injuries [13]. Pacing is usually defined by traditional time and motion studies, although one more acceptable option found both effective yet also tolerable, is the “85-rule”, viz. 85 % of the standard work carried out is carefully timed to an optimum pacing [24]. As such, in his seminal work, Berggren criticizes strongly line production and thus presents several cellular solutions as alternatives to line and lean production.

Cellular manufacturing is a type of combination of these two systems. It is flexible according to its capability and more effective than functional production and lead times are shorter. Since there is only one point to control i.e. the cell itself, it is also easy to manage. The cell can incorporate many activities and machines yet capacity utilization rate can still fluctuate. Nevertheless, effectiveness is still usually less than in line production, although its employees are often better motivated and self-guided, which will then compensate against the overall costs. Employees are often organized into multi-skilled teams and work cycles are longer than in line production. [23.]

All three of these options existed in Salo, which is common in production that covers the whole range of manufacture from raw materials into finished products. Nevertheless, in this project there is the desire to move away from functional production, and towards cellular manufacturing and line production, though some segments particularly in prefabrication may remain for now.

4.3 Value stream and flow in operations

A value stream consists of several single operations which are connected with minimum waste e.g. waiting time or movement between operations, inventory or excess space minimization. All such waste is common in functional “push” production systems, where multiple points are scheduled [14]. An ideal and true value stream is a one piece flow system, where operations are connected, although this is extremely difficult to achieve and nor always even practical [14].

In layout planning, there are several reasons to eliminate waste. Machines should be arranged as close as possible to one other i.e. close coupling. However, limitations will arise e.g. safety regulations, but since every square meter has its cost, otherwise all excess space should be minimized as much as possible. Further, the elimination of excess space will then also enable the movement of material without trucks. Of note is that in any case, any extra space tends to accumulate unwanted material. As such, the close couple arrangement is always preferable.

Thus, all material movement distance required in operations, should be minimized as much as is feasible, which will reduce the time used in non add-on value activities, such as transportation. Such close coupling between material and machines will also result in inventory more real time operated and easier to control visually, when it is close to its consumption point, instead of reliance on ERP-system (Enterprise Resource Planning) [14]. However, there may still be items which are prudent to store in the centralized warehouse.

Empty spaces have a tendency to accumulate with all possible materials, especially those not needed, even, that should really be elsewhere. As such, the organization for the minimum possible space required for every machine, is the best preventative measure against this. For Henry Ford, close coupling was considered especially significant and in his book he boasted that his company's machines were probably arranged the closest than in any other factory in the world at the time [17].

Improvement and development should be based on collected data. For time, the majority of the data is simulated or estimated, but comprehensive time studies have never been carried out, which means that attempts to gather data at a detailed level can be wasted; indeed, unfortunately this proved to be the case in Salo, where reliable phase times do not exist for the current product portfolio.

Since the objective in lean is to eliminate waste, which in this case study, meant to reduce the number of flow steps and organize the required steps as close to one another as possible, to achieve this purpose of the project, a benchmark for standardization, the team concluded to collate a so called “spaghetti diagram”, in order to comprehend the overall process and activities. To follow any product’s and material’s progress from the receiving dock to finished goods and through all of the steps required to produce the product, is a practical and easy method to reveal material moves in a process with ease: material flow can be traced onto a plant layout, that is, the so termed spaghetti diagram.

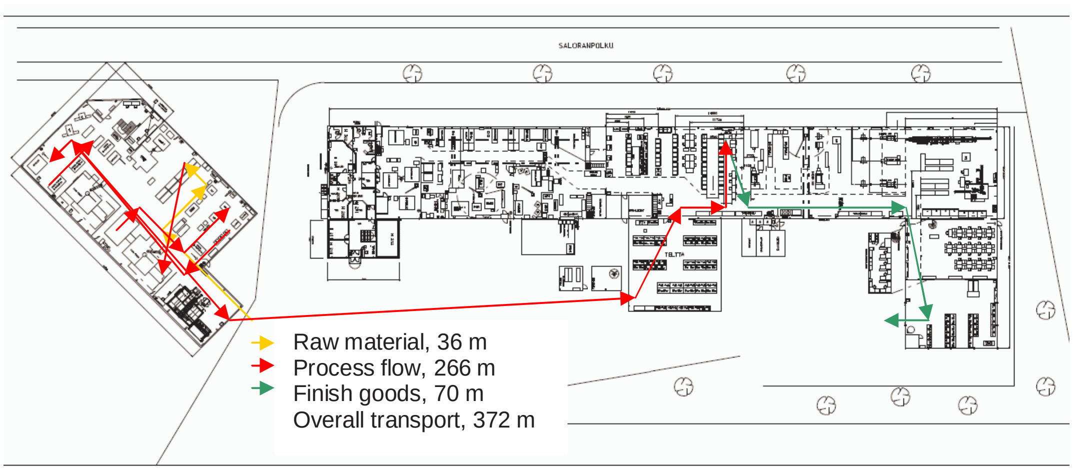


Figure 5. Spaghetti example.

Figure 5. illustrates the material flow for Case 1. In this current state layout, the case study product is manufactured from one piece and must travel 372 m before ready for dispatch. As such, it becomes immediately apparent that this distance is too excessive. Such “rough mapping” was already enough to convince the team that elementary changes were required. By following the red line which delineates the WIP-material movements, it becomes clear that moves between the individual operations are altogether, as long as the whole move between the halls.

4.4 Case 1.

Case 1. was the current situation before the layout was finally changed. This product had only recently been introduced and put into production, in winter 2009. High demand and business opportunities were forecasted, but almost immediately after production commenced, price reduction became required. Fortunately, having used the ‘spaghetti’ flow trace investigation, the Salo engineering department could already explore more effective manufacturing solutions.

The routing at that time was as follows:

1. Turret punch press, blank cutting
2. Press brake, 1st bending
3. Press brake, 2nd bending
4. Power press, formation
5. Press brake, 3rd bending
6. Final Assembly

At the bending process problems particularly arose. As a result of the product's bulky size and number of edges involved (16), three separate processes were required. Tolerance quality issues arose even at the first bending stage, and for the second and third processes, only two press brakes were suitable. Also, with the appropriate tools not yet considered, the blank cutting phase also proved too slow. Further, only one turret press with the required features and capacity was available.

In theory, the assembly should have been straightforward, but because of the product's size, excessive handling was involved. Further, since it was physically separated from the other operations into hall 3., visual management of the assembly process was limited. All six operations required separated work orders to open and close along with material transactions etc., and as a result of this long routing with its multiple scheduling points, lead times became counted in days or weeks for 100 pieces.

In the engineering team's improved version of the product's manufacture process, the first bending process and formation were integrated. This required a simple stage tool, which was processed with a single strike. The blank cutting and assembly phases were also both improved, the first with a few more suitable punch tools and the latter with a special jig that allowed multiple pieces to turn at a same time while riveted. Assembly was relocated from hall 3 to hall 5, thus closer to press brakes. Further, the blank was created into ERP as an individual item, and the assembly of the finished good consumed the blank. In this way, the routing steps were reduced by two thirds i.e. from six to two operations, blank cutting and manufacture, which included the rest of the phases now as connected operations.

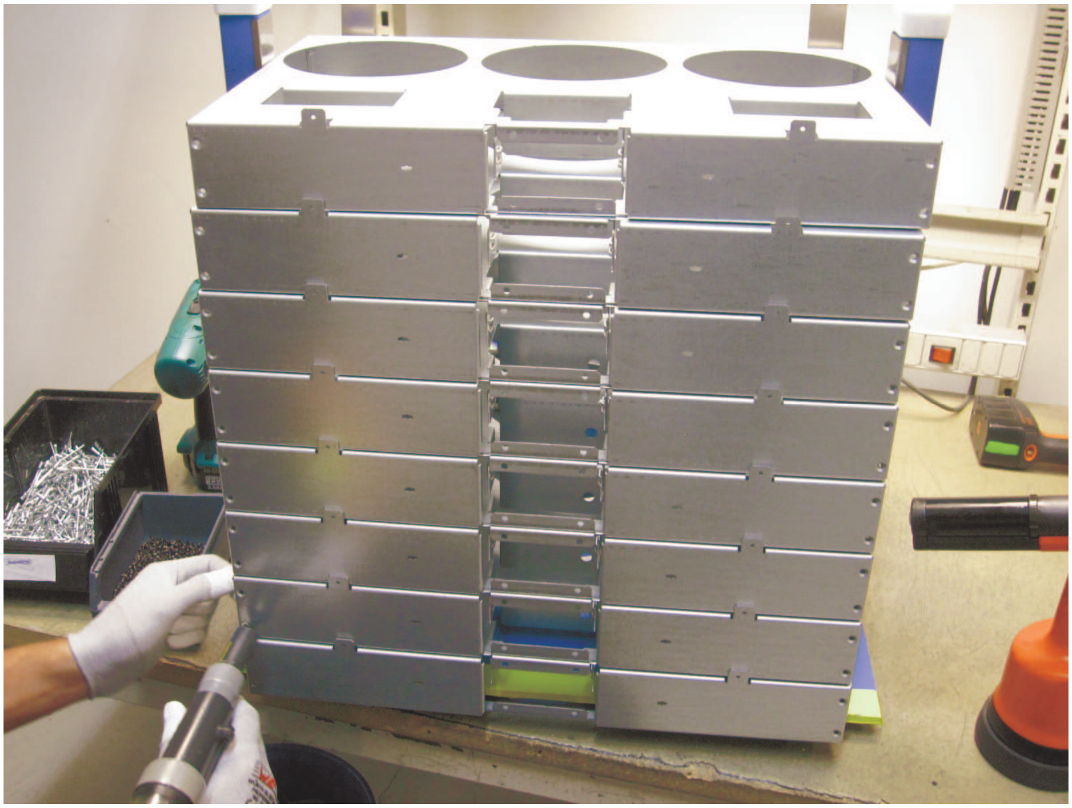


Figure 6. Assembly in rotating jig.

As a result, the blank cutting phase was separated and later operations were no longer dependent on it, as long as on-hand blanks were held in storage. However, it is difficult to create any connected flow if there are machines which cannot be specifically designated. Turret presses are often in general use. However, in Guadalajara the layout is based on value streams through the use of many turret presses. Approximately 900 different products are manufactured with 23 machines [25]. In comparison, at Salo, there are 850 products but with just 4 machines, which means that batch manufacture becomes unavoidable.

Thus, parts were produced in batches at the second phase, too (one pallet), but from the power press to the press brakes and assembly, the flow was continuous with a cycle time of 90 seconds which was the scheduling point too.

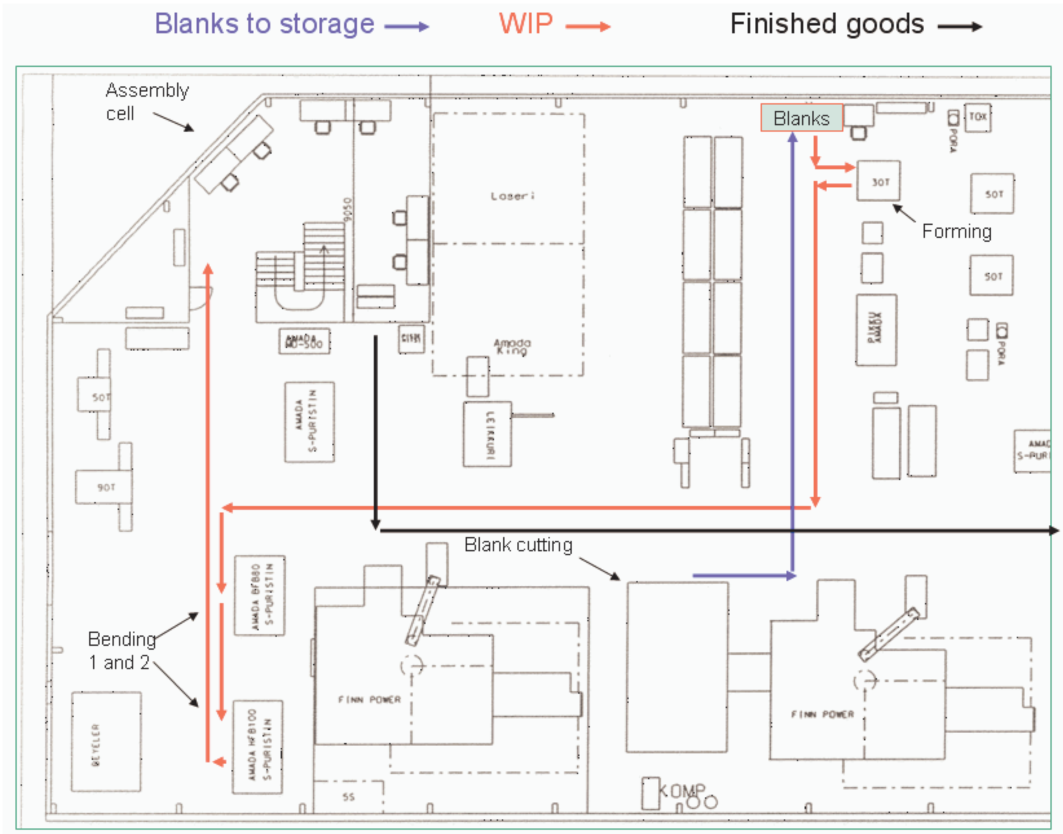


Figure 7. Spaghetti diagram for post-rearrangement.

After rearrangement, the process flow distance was reduced by approximately two thirds i.e. from 266 m to 80 m. If had been feasible to further relocate the power press closer to the bending, another 40 m more would also have been saved; but unfortunately, at the current time, no room for this was available. However, plans for the further development remained in lieu of the assembly of another product in a same cell which has a similar weekly demand.

In March 2009, the customer's forecasted demand for products was 500 pieces per week for the current year (2010), and for its overall future improvement, Salo management authorized a bending cell with a robot, which was sourced through the Toronto unit. This bending cell was planned to fit into the assembly cell, to produce components for assembly, and of note is that such equipment will then remain an investment, since relative to its age, it retains significant asset value. Unexpectedly though, the customer notified that the product's manufacture would henceforth be moved to China as soon as possible. Since the case study product of the other two products manufactured at Salo, were also part of the product family, all were subsequently also entirely relocated. Fortunately, costs already incurred could be considered acceptable, but regrettably, for this initial lean into practice exercise, the time and effort invested, therefore became fruitless.

5 The current state

The Salo plant had little opportunity to put into practice effective lean training; however, as the process was already familiar to the management team at a general level, and particularly to this instructor and author. In January 2009, new training sessions commenced under the guidance of Mr. Samuel Ponce, Corporate Quality Director at SSCI. Six training sessions were arranged for the management team, along with several other participants.

However, with other tasks designated to Mr. Ponce along with such business climate factors of cost saving requirements, topical interference (such as H1N1- ‘swine flu’ - infection prevalence in Mexico) frustrated his planned attendance in practice so that this plan was reduced by one third, with only four remote sessions eventually held. Fortunately, an opportunity to meet finally arose through a visit to Miskolc, in May.

Thus, it can be conjectured that as a consequence of these developments, since the Salo unit, being small, yet still profitable, with resources and efforts were understandably redirected elsewhere, the loss of the resources previously assigned and commitment to the lean project became compromised. Fortunately though, the training still took place and the lean project investment process remains ongoing.

5.1 Requirements, objectives and limitations

Nevertheless, unfortunately, it would soon become apparent from the training materials received, that Salo would not have the required personnel to undertake any significant or functional lean process transformation. Further, additional labor force could not be recruited and nor could current personnel be full-time engaged. In these circumstances, the Salo management team assessed the need for a project leader, along with a small team to assess what were the most important issues to solve, and which could be now realistically achieved in the current reduced cost investment business climate circumstances.

This team returned to Mr. Ponce’s lean transformation roadmap, which set the following objective: “transform a pilot value stream from traditional, classic, obsolete batch and queue manufacturing model into a continuous, logical lean flow model” [26].

With this guiding principle, the team soon encountered one major problem. Arising from the two separated production halls, it would clearly be impossible to organize operations into the close sequences without breaks between.

Several current material flows took place in both buildings. These were difficult, indeed troublesome, to organize between two separated buildings e.g. raw materials and purchased items were received into both halls and if any inspection was required, they were moved from hall 5 to hall 3.

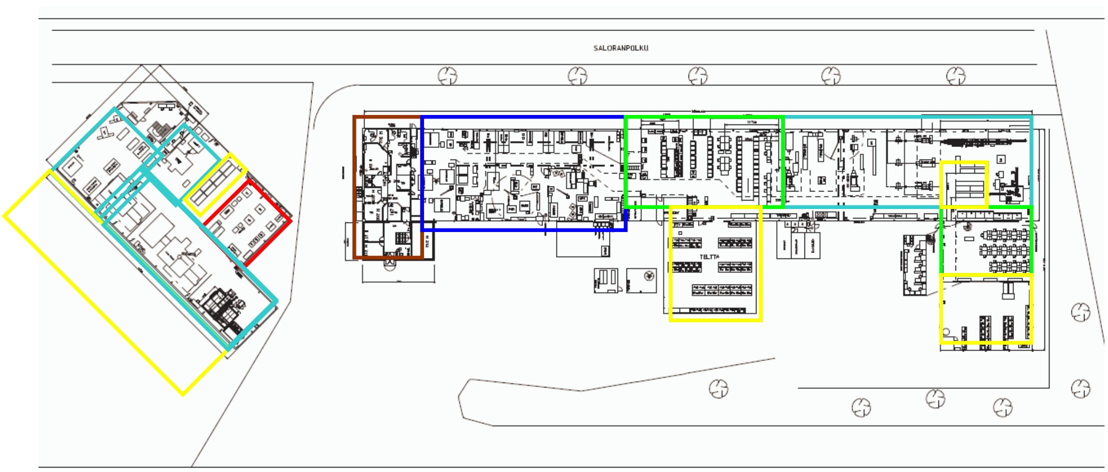


Figure 8. Overall premises layout.

Due to the absence of an in-house coating processes, significant amounts of parts are transferred to suppliers and back between the operations, defeating any continuous flow, and batches are required for the coating processes. Thereby, the team was tasked to research the options for a new layout and focus on points of disruption. For this, Mr. Ron Brown, Operations Director and experienced layout specialist from Miskolc, augmented the team in September 2009.

Immediately Mr. Brown criticized the existing layout and production model and consistently sought a solution which would eliminate hall 5 and rather utilize every available area of hall 3, the real estate. Hence, he formulated the very ambitious plan to fit all functions into the single hall 3. To achieve this solution, remarkable reductions in machinery and space would be required.

Inside hall 5, a 700 m^2 warehouse also existed, which stored redundant machines, materials and equipment and which presented as an instant and natural target for cost reduction, through its removal with sale of the excess equipment therein, to also help finance the project along with the scrappage of the unnecessary contents.

Mr. Brown scheduled the project to be completed by the end of the year 2009. The approach and objective would be cost reduction. However, the team had reservations on both the warehouse practicalities and the timeframe set required for the transformations. For these reasons, the team also explored alternative options, inclusive of left field brainstorming sessions, to make use of the team's full ingenuity abilities.

In addition to the two separated premises, further drawbacks in the current lay-out included that prefabrication was located into both buildings, which doubled transportation requirements i.e. assembly and WIP material, to be shipped out to the outside processes (OSP), plus incoming parts delivered, all occurred doubly in both buildings. Further, raw material, primarily as sheet metal, was also stored in both buildings, though all in rolls in hall 3.

5.2 Hall 5 activities

Hall 5 was deployed in 2003 when space was needed for turret punch presses. Over the years activities had moved back and forth between the halls for various reasons. At the beginning of the project it housed the following:

- 5 turret punch presses and a laser
- 5 press brakes
- 10 power presses
- Several small item equipment e.g. for threading, welding etc.
- A special assembly cell (see chapter 4.4)

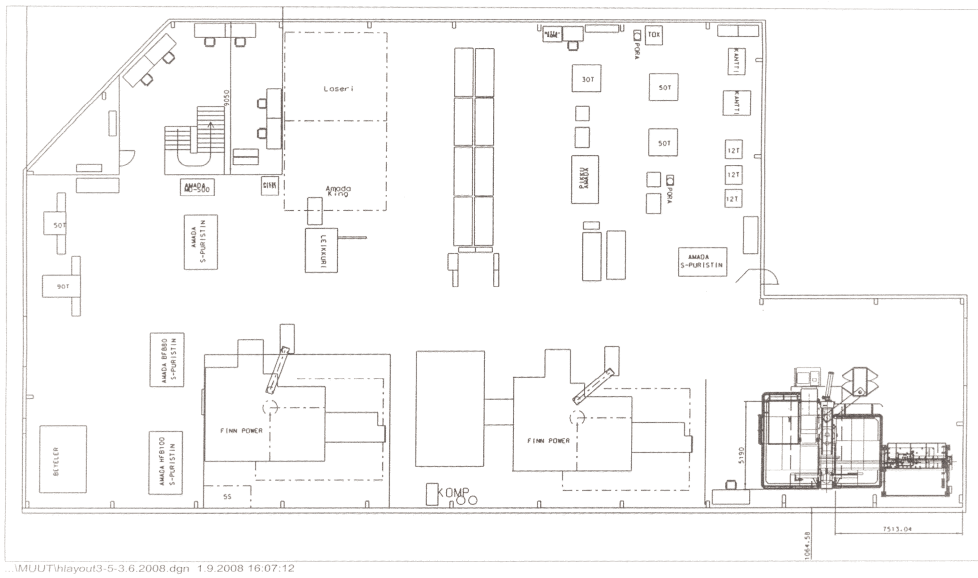


Figure 9. Hall 5 layout.

Fabrication was primarily components for the assembly with some marginal finished goods. In comparison to the power presses or press brakes, the turret punch presses are considerable noise generators, thus noise protection is required throughout.

Arising from their heavy weight and dynamic stress, the three main and largest turret presses required a special footing. Any removal would prove slow and be the most expensive single task, therefore could not be a primary option. All other equipment was lighter and easier to move. However, the assembly cell was already well streamlined in with the turret presses and press brakes, and demand for such parts was expected to increase.

Logistics were complicated, since the machine layout and components were often moved as in the worst case, into hall 3, and even back again. Nevertheless, the layout was still functional and space well utilized. Significant gains could not be expected in hall 5, but its location remained problematic. In the event of production increases, no extension options were available and contrary wise, any reduction would be difficult with the key functions and equipment located there. Furthermore, in consideration of the company’s difficult circumstances, to instigate such a costly option, is not only inadvisable, but unrealistic.

In the same building, but in a separated space was an additional warehouse, stored with old machines, tools, excess materials, plus used for occasional tasks etc. Of these were included some machines which still had a residual use value and were stored for later use and also customer-owned materials for which the company was under contract to store, which therefore had to remain, e.g. most of the tools were owned by customers. Nevertheless, with so many redundant contents remaining, along with pure waste material, although still valuable goods, the warehouse was a major potential cost reduction target.

5.3 Hall 3 activities

Hall 3, known as “the real estate” was a significantly more problematic area to be improved and more essential for the future. The building is divided into the five departments, viz: office, tooling and maintenance, dispatch and receiving, stamping and assembly. In the main hall, in addition to stamping and some assembly sections, is located one special fabrication line. Overall, excluding the office, 3260 m^2 exists for current activities. An additional 400 m^2 sized tent for non-heated storage is also available.

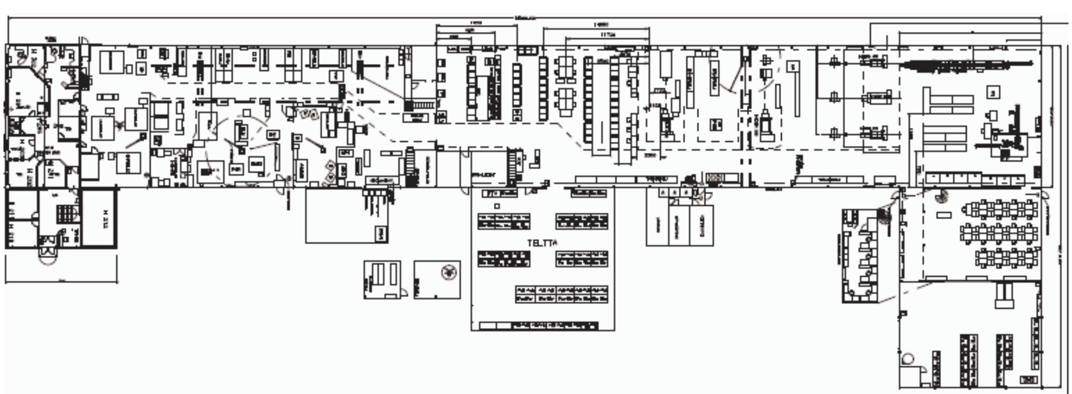


Figure 10. Hall 3, “the real estate” layout.

5.3.1 Tooling and maintenance

The tool room has about 800 m^2 in use (although not recently updated), housing nearly 30 individual machines for drilling, machining, grinding etc., including 4 wire cutting machines, plus individual lodges with tool racks and tables for each fitter, operated by nine laborers, including one mechanic, who undertake general maintenance. Only some minor changes had been made during the years at the same time when their number was decreased from 20 to 8.

As such, current space utilization was ineffective and also complicated. Most of the machines were used only for special purposes and therefore very rarely in operation. Excess capacity compared to needs existed and almost stationary set ups were possible. 25 % of the area was allocated for the department, considered an unproductive activity, which was a negative factor noticeable on entry to the tool room on e.g. during factory tours.

The capability to rapidly respond to design and manufacture assistance tools in-house, is always a significant advantage, by which the tool room had become a fully equipped machine workshop, as often required for prototype manufacturing and minor repairs. Thus, in addition to actual tool manufacture and maintenance, highly skilled professionals had designed and manufactured all kinds of custom designed gadgets required in production. Indeed, over the years, job descriptions had extended, while particularly hard tool manufacturing had declined.

5.3.2 Dispatch and receiving

Logistics and personnel were located at the very end of the building. Shipping and receiving occurred physically in a same place and finished goods were always transported there and from hall 5, too. This procedure has led to heavy traffic flows between the halls, being especially problematic with elemental exposure during winters. Moreover, because of narrow entrance and limited space in the yard, transport operation problems occurred. However, since the main assembly department was located behind the door, from this perspective the location was ideal.

As a result of the outsourced coating process (OSP), deliveries to suppliers and back are a daily occurrence. The blanks for coating are produced in both halls. The storage workers (2-3) must retrieve the goods from hall 5 or go there to dispatch them. However, transportation between the halls was not considered a major concern, and although problematic, could be minimized or rationalized.

5.3.3 Assemblies

Assemblies were positioned in two locations, the first in the middle of the building (right of the tool room on Figure 10). This area was mainly established for the restructuring of the Forserum plant in Sweden as described in Chapter 2. The major part of this production had already been transferred, when the project started, so that half of the remaining space was unused. Since, the remaining production did not need any further room anymore, the resultant empty space had been filled with all kinds of detritus and excess materials.

The existing assemblies were mainly of enclosures and fan units for telecommunication purposes. Most of the mechanical parts required were manufactured in-house and some coated in OSP. Plenty of purchased items existed too, so that the assembly cells were supplied from several sources and one cell was set up as an ESD (Electrostatic Discharge) protected area. Overall, the assembly area was far too large for the available demand, partially because actual demand had been less than expected, but technically because an efficient layout did not exist.

The second – front - assembly area was located at the end of the building, just before dispatch. A major part of this material is outsourced or purchased items. However in practice, the OSP is only a phase in item routing. Parts are manufactured in hall 5 with manual and turret presses, or in hall 3 with progressive presses, then dispatched to the subcontractor for coating, painting, printing etc. When the parts are returned back in-house, they are delivered to production or stored in warehouse.

The area was quite efficient with a robust layout and dispatch exactly adjacent to it. However, expansion room was restricted. Material is stored on shelves and into vertical carousels. These carousels were located on the opposite wall, which separated the assembly area from stamping. As a result, the lead hands responsible for the material supply, spent considerable time on the other side, which hindered communication with the team.

As such, the current situation was considered unsatisfactory, impractical, inefficient and moreover, cost reduction through space reduction, was essential. Despite the current economic recession, the financial position of the Salo unit remained favorable. As such, the management team decided to investigate all the possible alternatives for a new layout.

Incidentally, initially some nearby vacant premises were also considered and investigated; however none proved suitable and in any case, the costs of the required constructions and relocation were estimated at be too high. Consequently, the only option that remained was to reorganize activities in the current premises.

6 The future state

“Layout is a selection of equipment units that will enable the factory or the shop to turn out the best product in the least time with the least waste of power, time and stock.” is how Charles R. Allen described layout in his instructor’s handbook way back in 1919 [27]. Apt direction - simple, practical and true and given almost a century ago. With this idea in mind, the team set to its challenge to outline a new layout. To achieve any future state will arise from experiences in the past, with the vision of a desired state to be achieved. In so doing, the current state and its features must be assessed revealing its weaknesses as well as benefits.

In this respect, the aphorism ‘learning by doing’ is often used to describe lean development processes, and also highlights the process’ inherent pragmatic nature. Further, all such projects are often limited by both time and money, which mean that any solutions projected are often compromises with such boundary conditions. Nevertheless, realistic plans must still be formulated, with focus on the essential issues.

6.1 Brainstorming

Even though limited by resources in practice, it is often productive to attempt to think creatively, freely and, indeed, wildly – as ‘out of the box’, so to say - to explore all possible solutions and thereby reject early in advance those soon beyond investigation.

In August 2009, Mr. Ron Brown and Mr. Harri Kuittinen, Project Engineer, along with this author, met to commence a project. Also present at the first session was Mr. Johnny Nyman, Plant Manager, and as and when necessary, several visitors also invited.

Hence, this team’s first session working method was predominantly a type of ‘brainstorming’, with its target to initially outline all the alternatives on a conceptual level i.e. without any consideration as to cost or effort involved, to generate all possible concept ideas. Hence, at this stage, no limitations were considered; although with the prevailing economic conditions in mind, it is perhaps for this reason (and nor surprising) that no significantly extreme solution suggestions arose. Rather, the disadvantages and benefits of the current state were considered along with required features, the factory inspected and drawings and plans set down, resulting in this initial brainstorming session successfully hitting on three different concepts considered worth closer scrutiny.

In these, five different options were presented to the management team. Despite disagreement amongst the members on the specific concepts, a clear consensus still emerged on the importance of what should be of further investigation.

6.2 Layout study 1: All under one roof

The first alternative was to eliminate hall 5 entirely, rather than only its warehouse. This option would have provided the most significant future savings, through the immediate reduction of one third in space and thereby rental costs. Thus, despite massive changes in building and machinery, such savings would have rendered this major option worthwhile. However, naturally, its costs were likewise the most too, although which could have been partially offset by the sale of the resultant excess machinery.

Its most significant savings would be the relocation of all activities into one building. Transportation would reduce considerably and material flow becomes more logical. Several studies were made on this option, with different costs, and one of them is presented in figure 11.

In this option, the assembly would be placed in the middle of the building and receiving and dispatch department immediately adjacent. The presses would be aggregated close to the tool shop, this relocated to the end of the building. Incidentally, a notable reason for this action, is that the tooling department does not generate revenue, and thus is inadvisable to be any customers' first viewpoint on entry to the premises.

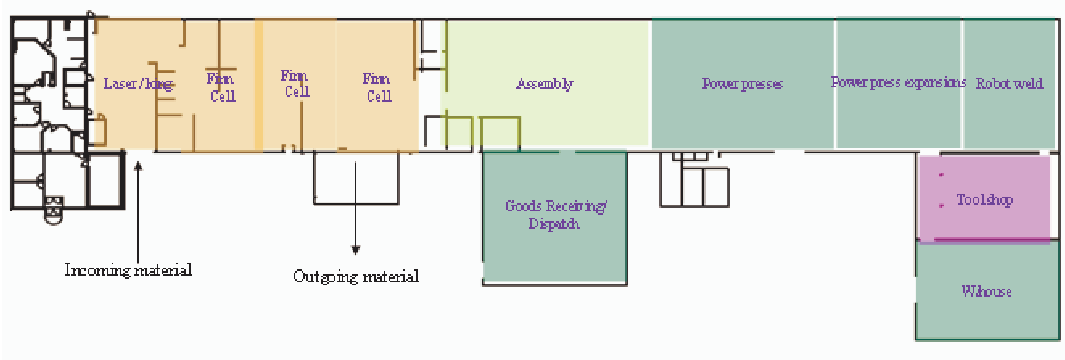


Figure 11. All activities located in one building.

This solution was mainly designed by Mr. Brown. The parameters were cost reduction and the utilization of Hall 3, “The Real Estate”, to its full potential, along with the sale of all excess machinery, plus all of that not in current effective use. Although favorable in general, this option also included several risks as well which had to be evaluated.

The most significant change would have been to reorganize the tool shop. In comparison to the current state, the whole department would have to be relocated into a one third reduced area, which would require a major divestment of machinery. From the point of effectiveness, this was feasible, yet to the detriment of capability. When evaluated, less than ten machines were considered as excess to use. Thus, in practice, it would have not been possible to locate the remainder of the retained machinery into the remaining area and in any case, radical reduction in quantity was evaluated as too risky. Total relocation would also involve reconstruction of the ventilation system related to the wire cutting machines, which would have proved prohibitively expensive.

Further, for this option, arising from the reduced limited space, reduction and modification of machinery would have also become necessary. Loading and unloading equipment would have to be detached from the turret punch presses and after which, unmanned use would have no longer been possible. Some presses too, would have to be removed, which would cause inflexibility in features and increased changeovers, even though the utilization of machinery would have become more effective. There was also an idea to create generic cells as, for instance, turret press - manual press – tapping, but the problem remained of space and the lack of potential generic products at that time; yet the idea itself was most progressive.

A reduction in the number of machines and features would also have resulted in a limited capability to produce the current portfolio of products, causing the manufacture of some products to then have to be outsourced, and even though there are products which have the potential to be so outsourced, since no resources were available to begin the organization of this process, that investigation into which product families would have to be considered with the related machinery and tooling etc., gave rise to too many uncertain questions to resolve for this option to be practically considered at the current time. Moreover, there would have been no spare space for any enlargement should the demand arise and storage especially would have become a problem.

Further, since both dispatch and receiving were located in a light temporary tent structure - but which is already planned to be removed - in the current state, the activities shown in fig.11., were located in an area which is designated as a warehouse in this option. Even though this would be a logical step, this area is not adequate for the purpose desired.

A further consideration result would be with restriction and limitation resulting from overall reduction, would lead to work performed in three shifts, which although would have increased the utilization rate of the machines and facility, but at the same time, would also require more control, improved availability of service and maintenance etc., which itself would also increase costs. Further, from an operational perspective, work in three shifts is stressful and a cause of health risks and likely increase sickness absence and/or staff turnover [28].

Even though the positive utilization of machinery, facilities and labor is essential for business, for these reasons, the management team rejected this alternative, as considered both too expensive and a risk for the business. Further, it would have involved so many changes and tasks with such schedule, that overall, the team doubted its feasibility.

6.3 Layout study 2., factory extension

With rejection of the first alternative, the team considered possible extension. In this way, hall 5 would be eliminated and all activities located into an extended single building. Depending on the changes, its cost would be approximately the same as, or possibly less than, option one. Dismantlement of the tent structure would be required, which in any case was envisioned as necessary for the future. Although several layout studies for this were considered (see figure 12), none came to fruition.

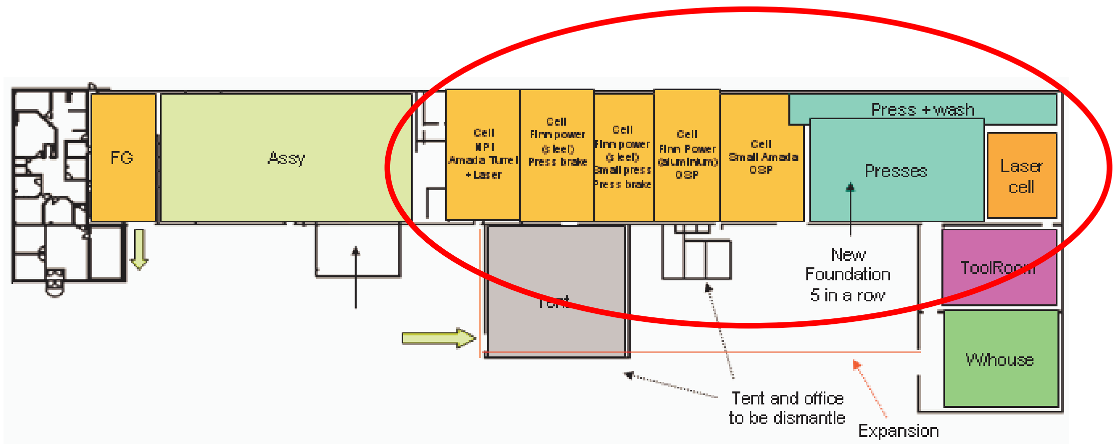


Figure 12. Hall 3 with an extension.

In Hall 3, narrowness had always been problematic, but a building permit for an approximately 1000 m^2 expansion, to thus double the width of the construction, already existed, which would then be sufficient to requirements. However, based on a overlong payback period, the landlord rejected our plant manager's suggested rental sum, meaning that negotiations for this option unfortunately failed.

Further, in any case, this option would have delayed the project for a minimum of six months and complicated logistics during its construction period. Nevertheless, it is worth noting this option remains the most desirable, with the relevant permit still valid for the foreseeable future.

6.4 Layout study 3., reorganization of the current premises

With the rejection of these two previous options by the plant management, the project team commenced to outline a new layout for the current premises. The team had already concluded that the most important area to improve was hall 3, and particularly "the real estate", delineated in red, in figure 12., and concept as described. This was presented to the management team, which accepted this plan. At this point, Mr. Brown now exited for other duties in Miskolc leaving this author and Mr. Kuittinen to plan a new layout, but now with the assistance of Engineering Manager Mr. Hannu Alatalo.

During the evaluation process, the team had already decided to leave one production line untouched irrespective of which alternative finally selected. Since there is an integrated progressive press and wash line and laser cell (see figure 12.) which is designated for one particular product, located at the end of the building with its machines positioned as close couples, despite all remaining being possible to relocate, any relocation of this line would actually, likely prove to be a very expensive task; hence, since the team could find no further significant options for improvement, this option was also rejected.

During the evaluation phase, costs and future savings for different alternatives were estimated. The selected option (three) yielded a 13 % annual savings in rent and “one building” solution would yield 31 %, but costs were 32 % higher i.e. approximately the same sums as the projected annual savings. Consequently, the team was dissatisfied with these figures, but both team and management remained convinced this option would be the correct one.

7 Planning process

On decision that both buildings would remain but that the warehouse be eliminated, the team started to investigate the different alternatives thus available. The baseline for the project was as follows:

- Current premises without the warehouse
- No significant reduction of machinery in production, the number of turret presses and progressive presses to remain
- Tool room restructure, 1/3 reduction
- No expansion, but preparedness for future remains
- Flexible layout, easy to reduce / increase

Several options were considered at the conceptual level before detailed measurements in premises were undertaken. Two are partially described in figures 11. and 12. The most critical choices were heavy progressive and turret presses. These cannot be moved often, since half of the costs were related to them, therefore, it was critical to first find an optimal solution for this machinery. As such, it was considered they remain in situ, but all considered this option to be unsatisfactory.

7.1 Conceptual solution

After review of several options, the team opted to continue along the lines as illustrated in figure 12. and develop it further. The transfer of the tool room would prove to be not only a challenging task, but also too expensive, and therefore unnecessary as hall 5 would still remain. Eventually, the team opted for the solution where the tool room would remain in its current location, but reduced in area. The assembly, related warehouse and dispatch would be relocated into hall 5, and the current warehouse remain for OSP goods and for machinery and tools which had to be retained. This concept is presented in figure 13.

Figure 13. New layout concept.

This concept would prove to be acceptable to the team and despite some compromises required, yielded some major benefits. The turret presses were well positioned in respect of material flow and the press brakes close coupled with them. The progressive press section was far more compact and the space reduction achieved approximately 30 %. More space was designated for the assembly which is considered as a future state opportunity. The warehouse is relatively large and in any case, is considered as waste in lean thought. However, it is possible and indeed necessary to reduce in any future development.

During the process, the landlord notified that a new tenant required an extra entrance, so the company's leased area was reduced by a further 50 m^2 (red area on figure 13.). However, this did not prove a problem, as there remained extra space which was not in effective use, and with no further opportunity to divide the current areas into the smaller sections and thus gain in rental reduction, gave a fortuitous development - even if minor.

7.2 Design of hall 3, the “real estate”

When the concept was agreed and accepted in general, the team began to design a detailed layout for hall 3, in September 2009. Precise measurements indicated that the turret presses are possible to fit into the available space, although, there was a risk that the size of the products could be a problem in future. Three of the turret presses required a special footing and space was so limited that the tolerance for positioning was just 10 cm, to mean that in practice there would be no option to further relocate them later. However, this risk was considered minor and one turret press was still capable of manufacture for large products too, should the need arise.

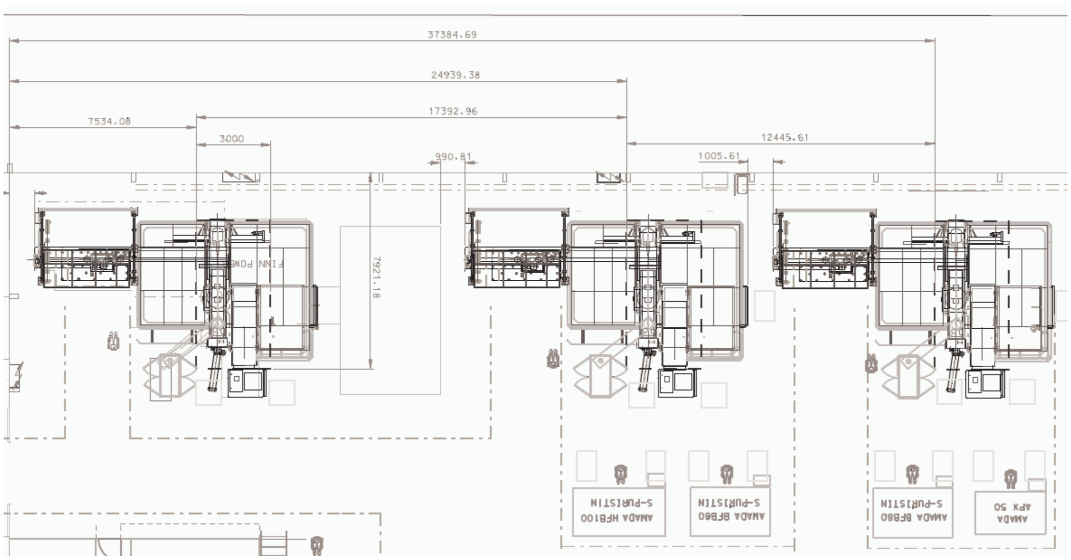


Figure 14. Dimensioned drawing for footings and turret presses installations.

The fourth turret was a lighter model, thus not requiring any footing, which allowed it to be easily moved, if required. As shown in figure 14., the machines were aligned and numbered from left to right. Further, to create a flow from the turret presses to the press brakes, the machines were close coupled to the maximum extent since all blanks that require bending are produced with turret presses. Room then remained only for the trash cans and material to be processed.

The turret press section extended so far that the progressive presses section had to be reorganized. However, since it was decided that all the presses would remain, another solution had to be found. The first attempt was an option where one press was located between the washing machine and laser cell, as the fifth special and small punch press was preferred to be among the others. This would have provided more effective operations and noise would have been reduced, too. However, this option had to also be discarded as the press would then have blocked the area too excessively.

The next option was to utilize the old footings and rotate the presses, which seemed far more feasible and saved the costs of one extra footing. However, the presses were still too long to fit. The required length of a progressive press depends on the material thickness and width. After some probes it was established that the length overlapped for most of the presses, because such products no longer existed and furthermore, were improbable in the future too. Thus four presses were reduced by 100 – 150 cm in length. This is a good example of the status quo, where in the absence of continuous improvement i.e. if not urgent, do not interfere (viz. ‘if it ain’t broke don’t fix it’!)

As such, all the main machines were relocated, with team satisfaction for final space utilization. The sheet metal and press tool racks were located against the wall alongside the corridor, so that its space could be utilized for forklift operations when loading and unloading racks. Sheet metal rolls for presses were positioned between the presses as much as possible. The only remaining empty space in the “real estate” was a minor 20 m^2 near the entrance, which was designated as a punch press tool maintenance and storage area.

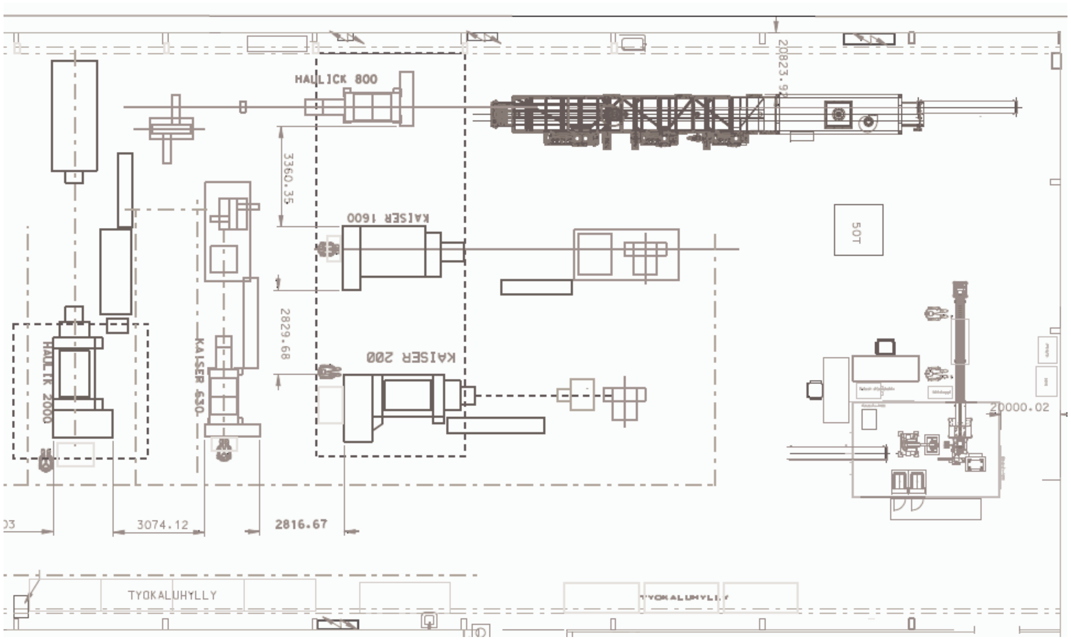


Figure 15. Progressive presses, washing line and laser cell.

7.3 Tool room design

With the rejection of the tool room and maintenance move, the team sought alternatives to reorganize it and thus reduce its area. One large “waste” area was the grinding room which has heavy use occasionally, but overall its utilization rate remains rather low. It also blocked the corridor and progress through the area was in a zigzag. However it is essential for tool manufacture and maintenance and must be isolated area because of grit. Mr. Alatalo commenced redesigning a new layout for the tool room wherein the grinding room is relocated and the whole area reduced by one third.

Again all else was moveable with the exception of the wire cutting machines. To attain the sensitive process of high precision, such machines require stable conditions, such as temperature and humidity and vibration must be eliminated, thus requiring location as far as possible from presses etc., which otherwise cause vibrationary disturbance. Further, ventilation was more effective in the current area, which thus remained, and one of the four machines could thereby be eliminated (leaving three).

Another challenging apparatus was a crane, installed on the ceiling. This was difficult and expensive to move entirely and such lifting devices are strictly controlled by regulation. Nevertheless, modification was possible by shortening it from one end with extension to the other. The whole length was not needed, but it was not properly positioned for the future use. The task was still challenging and expensive but essential and after reconstruction the crane could also service a wider range of machines.

Flow and close coupling and such lean principles are not particularly significant issues in tool room operations, but all the improvement steps are still of value to implement. The resultant new layout for the tool room is shown in blue on figure 16. and one major improvement was the elimination of the zigzag corridor arrangement, after the grinding room was rebuilt adjacent the tool room. The area was reduced and the vacated area then usable for other value added activities.

Figure 16. Tool room and manual presses.

Manual presses and a laser cutting machine were relocated in the noted area designated in red. The majority of the parts in this section come from the turret presses and progressive presses for phases, which cannot be operated in these machines. Flow is mainly via small special turret press (at lower right corner in figure 16.) to the presses and the majority goes to the OSP and from where they return to the assembly. The laser is located in the upper right.

Overall, this area was unsatisfactory, yet some restrictions could not be disregarded. The transposition of the turret punch and laser would have provided better flow, but with the low ceiling above the turret punch (designated by grey broken line in figure 16) the laser is too high to install under it. Further, when in operation, the laser is a significant heat producer, which becomes of risk to the wire cutting machines. For this reason, it is located as far away as possible with the existing option to direct its heat out, via a compressor room located on the 2nd floor next to laser. However, to date, the laser has not been utilized significantly rendering current ventilation as adequately efficient, but this may well become an issue for the future, so that an effective plan to eliminate this problem will arise.

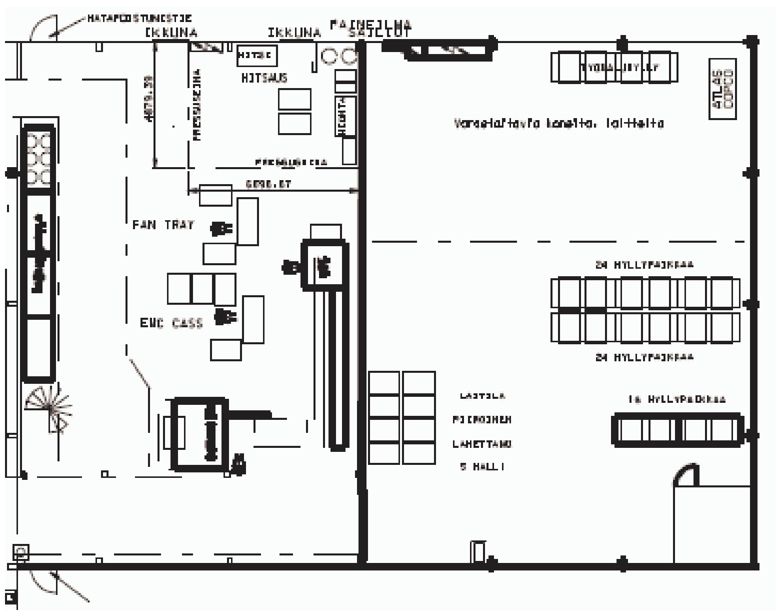


Figure 17. Secondary activities and warehouse.

All remaining activities considered as supplemental were located at the end of the building where the assembly and dispatch were originally located (figure 17.); e.g. welding, a shearing machine plus one single press for aluminum profile cutting, which although still in regular use, is not necessarily daily. One assembly, for which there is a considerable fluctuating demand, along with press tools seldom in operation, were all planned to be relocated to this location. In general, this area was considered to be versatile and easy to reorganize, as required.

The old dispatch section was redesignated for OSP parts and miscellaneous materials e.g. excess machines, materials and spare parts. A few machines which had some residual value, thereby of resale value, but which, currently there were no resources for the active marketing of such, were thus designated for storage in the meantime.

7.4 Design of hall 5

With all the fabrication and related machinery planned to be relocated into hall 3, the assembly and warehouse remained to fit into hall 5. Arising from its shape, it appeared to be practical to place the assembly on the opposite side and warehouse racks on the other, and so divide these areas with a corridor. The assembly itself was divided into two sections viz. enclosure assemblies and front plate assembly (green and blue in figure 18.) Dispatch is located at the right end.

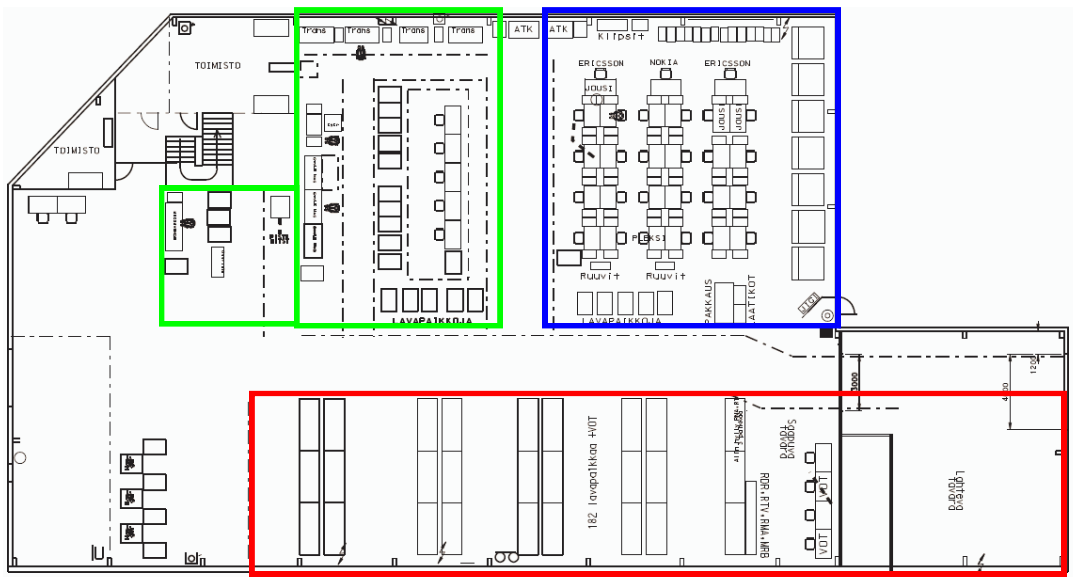


Figure 18. Hall 3, assembly, warehouse and dispatch.

Material supply for front plates was organized as much as possible into carousels as a point-of-use material storage. This allowed cell associates the option to manage the re-order of point-of-use inventory [29]. The remainder of materials, packages, accessories etc. were located into racks. Whilst awaiting dispatch, finished goods were stored for no longer than is necessary.

The most common configurations for assembly and machine tool cells are U shape or straight-line design [15]. In the latter, everything is in line shape, though benefits might also accrue from the U shape layout too. Assemblies were moved as they stood and improvements were obstructed arising from more urgent issues. In case 1. (as discussed in chapter 4.) the U shape configuration was utilized. For case 2. a linear assembly solution will be dealt with in chapter 9.

From a planning perspective, accomplishment of hall 3 improvements was more essential, yet more difficult than hall 5. (as given in previous chapters). Hall 5 will be the area which can be obviated in future, if required. As such, the layout was left to be flexible with ease of reorganization e.g. activities are easier to move into other locations e.g. a possible building extension. Since there is an entrance at both ends, any necessary area reduction can be possible. Further, the warehouse is relatively large at this point enabling the creation of any future required space. This planning phase was finished in October 2009 and preparations started.

8 Execution

Since, it would have been uneconomic to halt production, those machines designated relocation had to move in stages. As such, the re-installation area had to be fully prepared when any move commenced, as temporary installation is not feasible for large machines. Thus, the assembly cells which were located in the targeted area for the machines' planned relocations, had themselves to be moved temporarily. Further, the planned re-footings required a drying period before installation and these areas had to be left unobstructed.

For the oldest turret punch planned to be replaced with another (already held in store from Toronto), already required far too costly repairs, rendered it prudent to merely immediately scrap it, and by so doing, also then released space for temporary assembly installation, too.

8.1 Turret punches and progressive presses

When the targeted machine was dismantled, the existing assembly cells were moved from hall 3 to that particular area to give way for the re-installation footing constructions. Two of these (figure 19.) were supposed to be in that area and one possible to construct when the tool racks were removed. Since these moves were temporary operations, they had to be relocated when the targeted machines were resited into their new positions. The turret punches required subcontractor involvement.

Figure 19. Floor is opened and rebarred for concrete footing.

Two weeks after the renewed footings were concreted, mechanics began to dismantle the first turret punch, while the previously (Toronto) stored one was transferred into hall 3. Two machines were still kept running during the process until the former was re-installed and deployed. As such, all three heavy turret punches were moved and also operational before Christmas 2009. Lighter machinery and the laser which required less pre-move dismantlement were left for later removal and relocation.

Concurrently, several progressive presses were also moved, operations which required no external assistance other than electrician. Thus by January 2010 all the turret and progressive punches were fully reinstalled and operational (figure 20.), meaning not only the most challenging, but also expensive aspect had then been accomplished, allowing the team to commence reorganization of further activities.

Figure 20. Turret and progressive presses installed in the “real estate”.

8.2 Tool room and manual presses

Before removal of the front assembly was possible, the manual presses and press brakes had to be first moved, and before this, the tool room had to be reorganized and grinding room dismantled. To achieve this several temporary locations for racks, machines and operations were divided into several places.

However, at short notice the landlord of hall 5 notified that the warehouse was to be reconstructed, resulting in a halving of the company’s area within two months. This unexpected development demanded resources and space which were already allocated elsewhere and hence the team had to immediately reconsider the whole operation planned.

Since the sequence of the move could not be altered, the planned schedule had to be sped up in the production areas, yet slow down in the tool room. To date, overtime investment had not been required, but would now be a necessity for the moving crew.

The tool room was emptied, partly to have a space for presses, which regrettably caused some disarray and transport problems, although this was preferable than to such problems in production. Over one weekend, with no outside assistance, either, the manual presses were moved. To avoid risk of delay to any deliveries, production stoppage was kept to minimum. In just two days of production halt, the presses were operational and the tool room rearrangement continued with subcontractor's assistance.

8.3 Assembly and case 2.

The front assembly move started immediately after the presses were moved. Production was stopped for only one day and all portable items moved. Carousels, racks and components were moved at the same time, so that material was not separated between the two buildings for too long. Incidentally, during this process, Salo had won a tender on the new front model, which required new production methods and capability to achieve the optimal manufacturing method i.e. in comparison to current production models, the new front plate was to be produced in bulk, and demand would double the current weekly production.

The traditional method is for an individual worker to assemble the whole front plate from start to finish. Plates are set on a jig, ten pieces at a time, using two different jigs as the pieces are fastened with screws in different directions. Plates are individually moved, one by one, onto the second jig. However, unfortunately, for the amount involved in our relocation task, this method would be too slow.

Thus, the engineering team began to look for new type of assembly frame which could replace the current jigs, so that the parts could be set on the jig only the once, this is despite the original “one jig” idea had previously proved unsuccessful, and two jigs remained unavoidable.

A further improvement was that parts could be moved from one jig to another in a batch rather than singularly. Thus, although this flew in the face of the pure one-piece-flow concept, it provided the required significant improvement in the assembly cycle time. This jig adaptation was actually, more like a reduced setup and in any case certainly a reduction of non value added activity.

Another significant improvement was an investment in pneumatic screwdrivers with automatic feeders, rather than the traditional air powered hand tools. Hence fastening time was halved and precision improved when orientation was similarly improved. Eventually, the linear assembly cell was divided into three sequential phases instead of the prior one. These sequences and jigs are shown in figures 21-23. The overall improvement in the assembly cycle time is demonstrated in table 1. Final assembly phase (figure 23) was a new operation, therefore, it is not included into comparison. Cycle time for one piece was reduced from 57 seconds to 18 s and even there were two workers instead of one the improvement were 37 %.

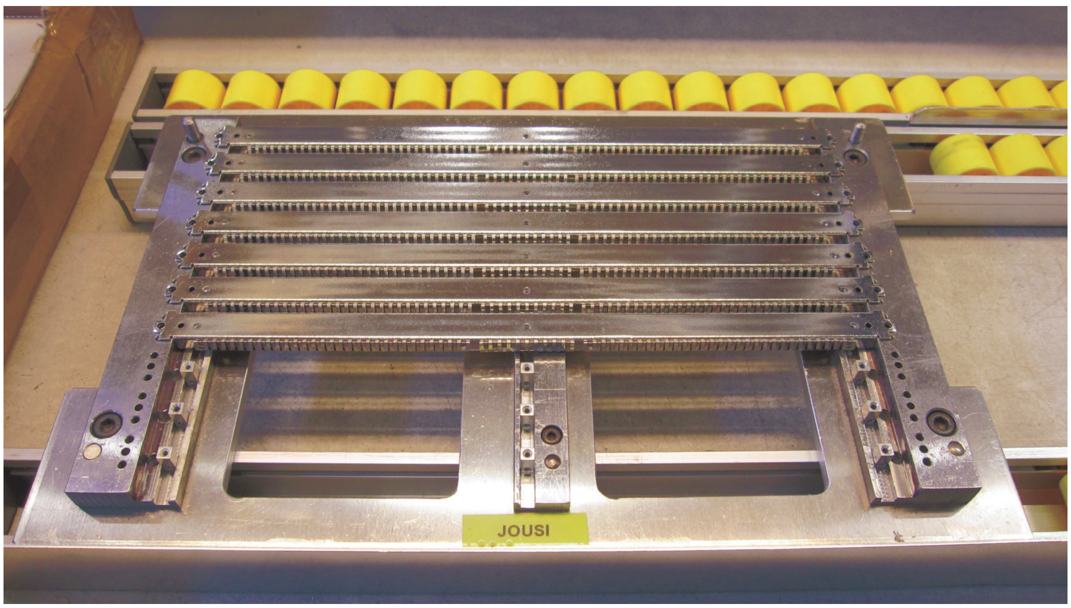


Figure 21. Parts in jig at first phase.

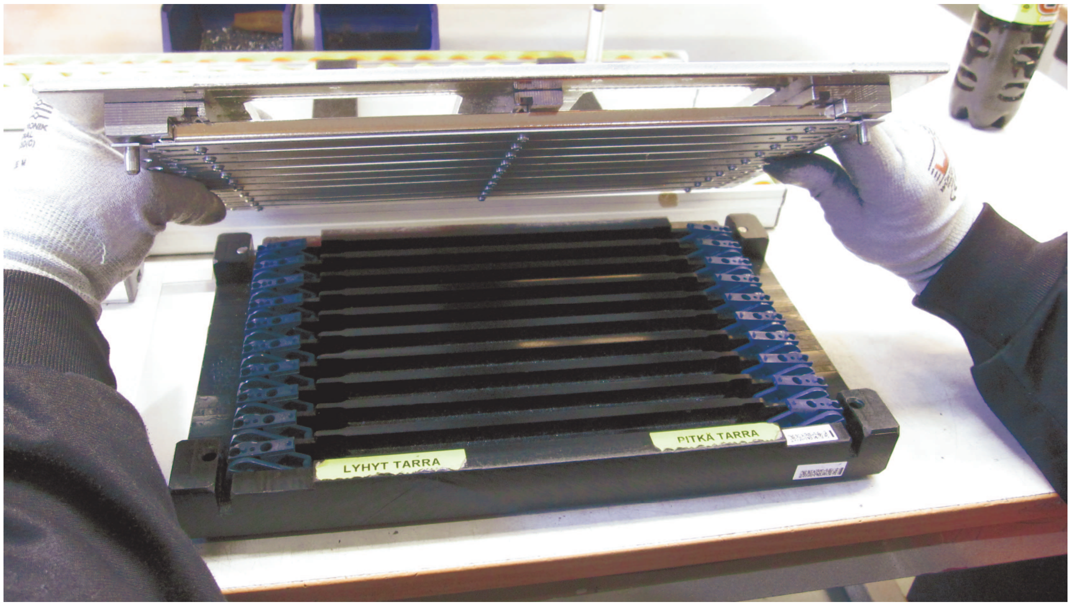


Figure 22. Shifting parts onto next jig at second phase.

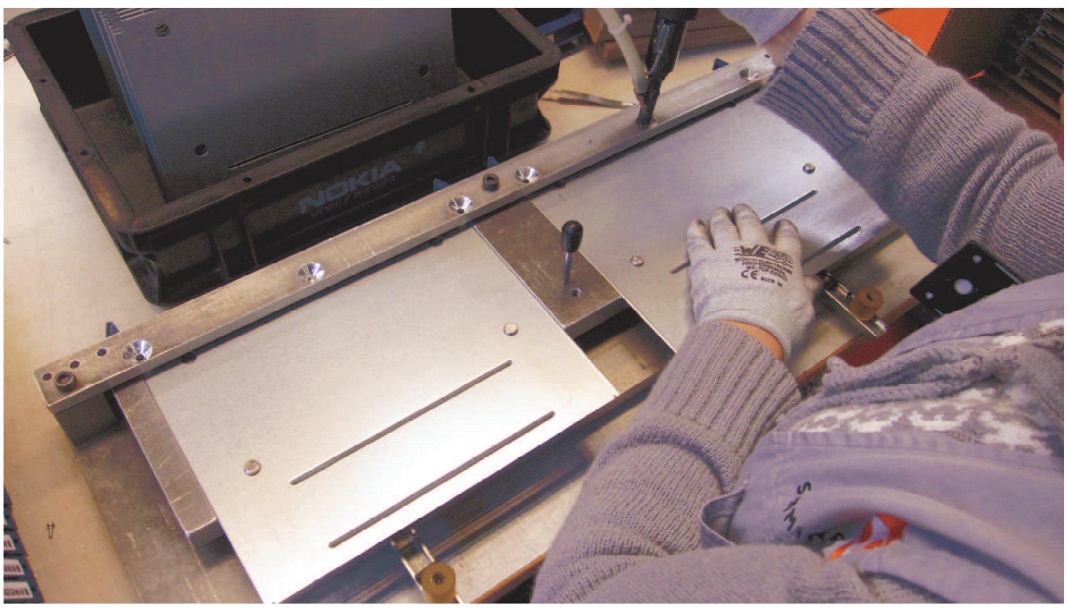


Figure 23. Phase three, final assembly.

Table 1.

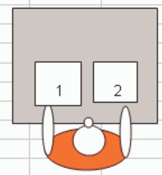
Case 2., current state

JIG 1 (10 pcs)

Install fastening pieces, 30 pcs	56
Install inner parts, 10 pcs	29
End screws, 20 pcs	32
Install outer parts, 10 pcs	50
Fastening screws, 30 pcs	133
Total for 10 pcs	300

JIG 2 (5 pcs)

Single preassemblies for the jig, 5 pcs	20
Install handles, 10 pcs	44
Move to next stage 5 pcs	20
Install new handles, 10 pcs	50
Total for 5 pcs	134



One operator, 300+134+134=568 sec., lead time for one piece 57 sec.

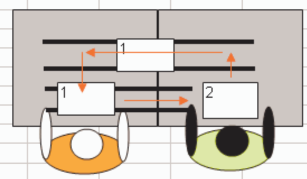
Case 2., future state

JIG 1 (10 pcs)

Install fastening pieces, 30 pcs	56
Install inner parts, 10 pcs	30
Install outer part frame, 10 pcs	8
Guide plate	
Fastening screws, 30 pcs	
Drop end screws, 20 pcs	90
Total for 10 pcs	184

JIG 2 (10 pcs)

Join jigs	11
Fasten end screws, 20 pcs	45
Separate jigs	
Unfasten pieces, 10 pcs	
Move jig back	23
Install handles	69
Remove scrap from frame	15
Total for 10 pcs	163



Jig 1 moves between stages, jig 2 is stable.
Two operators, lead time for one 18 sec. (according to stage 1, 184 sec.)

Thus in comparison between case 1 and 2, in the long term, the latter was far more successful, since such activity already existed in house. Improvements were inevitable, based on markets and possible to utilize for a wider range of such assemblies. These investments remain applicable even if the relevant assembly production were to terminate as any spare capacity could be utilized in any similar assembly work. However, ironically, it is quite likely that the investments required would not have materialized.

8.4 Warehouse and dispatch

Some enclosure assembly cells still remained in their temporary locations and press brakes had not yet been moved, as the area in hall 3 had to be clear, until the turret punches were set into their new positions.

Moreover, functioning electricity installations were not delivered on time, therefore the press brakes move were postponed. In general most of the delays concerning this project arose from the lack of electrician labor. Also, the team had no proper expertise in this area, therefore, subcontractor resources were not allocated adequately.

Eventually, when all the machines were moved into hall 3 and the temporary assembly cells relocated into their final positions, the warehouse was largely able to be reconstructed as planned. Arising from air drafts caused by the repeatedly opening door, dispatch had to be separated from the main hall. The area was divided with a light wall and the entrance from dispatch into the main hall was covered with plastic strips which prevented draft but still enabled forklift traffic access.

Arising from the reduction to the current warehouse due to reconstruction work, some machinery was moved into the main hall, and part of the planned warehouse area thus became alternatively reserved until such machinery was cleared. This resulted in that all the racks planned could not be mounted on time and left some materials in hall 5 or the tent. The status of the excess machinery remained unclear and its disposal task became more challenging than expected, since the demand for such machinery on secondhand markets or in other plants, was non negligible, and as such the warehouse could not be finalized until the excess machines were solved.

However, on the whole the project progressed as planned and in the event of any delays, the team switched to alternative activities to stay on schedule and prevent stoppages in operations.

The tool room rearrangements proceeded under Mr. Alatalo’s supervision. The welding section which was a part of the tool room was relocated to the end of hall 3, and the laser cutting machine was transferred into its place. The modification of the crane and ventilation system was the last operations undertaken in the tool room.

However, further challenges arose when the landlord announced that warehouse would have to be vacated earlier than planned at end of March. The end of hall 5 had to be reserved for the machines and the subcontractor instructed to close the job. Negotiations with possible buyers resulted in a contract with a dealer who bought all the machines, bar two, as a batch. These machines were unable to be delivered before the end of April, at which time, the rest of the warehouse arrangements could then be completed, and in May 2010 the new layout planned was finally accomplished. (figures 24-25).

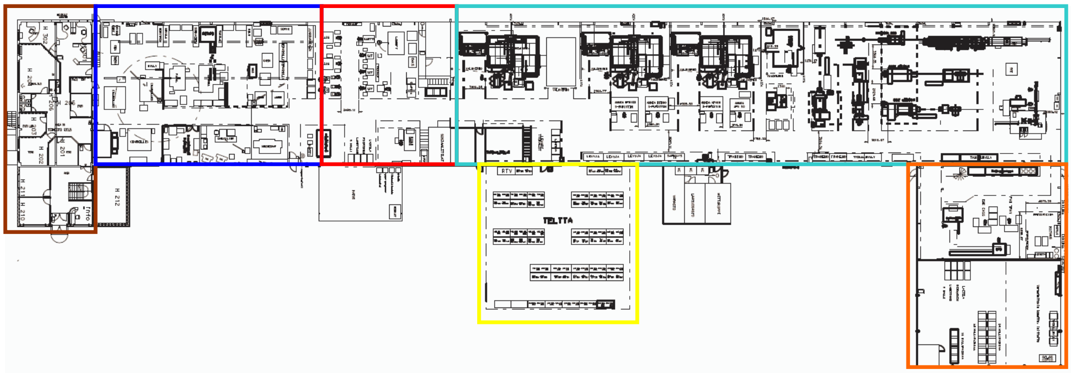


Figure 24. Hall 3 activities.

- ⇒ Office
- ⇒ Tool room
- ⇒ Manual presses, small turret punch and laser
- ⇒ Turret punches, press brakes and progressive presses
- ⇒ Tent
- ⇒ Miscellaneous activities, welding and warehouse

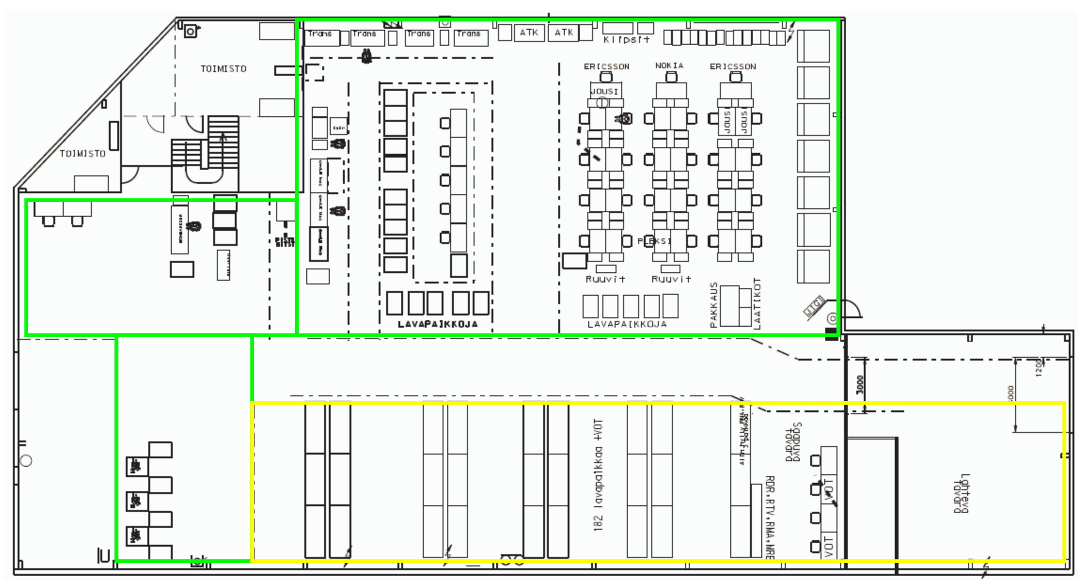


Figure 25. Hall 5 activities.

- ⇒ Assembly
- ⇒ Warehouse, dispatch and receiving

9 Conclusions

At the stage whereby the new layout was accomplished, many tasks and improvements which occurred during the process still awaited execution e.g. specific locations for pallets had to be reconsidered along with exact locations for some machines or markings on the floor, racks etc. Further, several small minor matters had to be solved and finely adjusted.

9.1 Economic objectives

On commencement of the project, several objectives were set and which could be considered as achieved. One was the reduction in space with concomitant savings in rental costs. The output of the operation was €50 000 annual saving in rent which was a clear economic target of the project. Further space reduction will be more difficult, although still possible, but the remaining area is contiguous and cannot be separated without reconstruction. In this case, landlords usually not prefer such operations, because of both expense and difficulty to subsequently lease out.

The sale of surplus machinery was also a cost target intended to also finance the costs of the project. This was not achieved as planned, mainly because two of the most costly machines remained undisposed of. That machinery which was sold generated €10 000 plus with some gratis services from the subcontractors involved. Further, a few machines were part exchanged for a new press brake, valued at €33 000. Overall costs incurred were approximately €150 000 i.e. that 40 % of the expenses were financed through machinery sale and space reduction. The payback period for the remainder is two years.

9.2 Lean objectives

Although lean methods and principles have been utilized in this project, but with the exception of case 2., since value streams were difficult to identify and its layout was not a genuine lean solution. Moreover, the current technology does not, for example, facilitate quick changeovers and flexible manufacturing in the desired extension. The future state layout achieved should be considered as a framework and hardware for future solutions and improvements.

9.2.1 Close coupling

Excess space is always wasteful and for which, close coupling is preferable in any production activities. Likewise, transportation is also considered wasteful and such close coupling will reduce distances. This principle is essential in value stream concepts, but which where difficult to define in this particular project. As such, compromises as given in figure 26., had to be accepted.

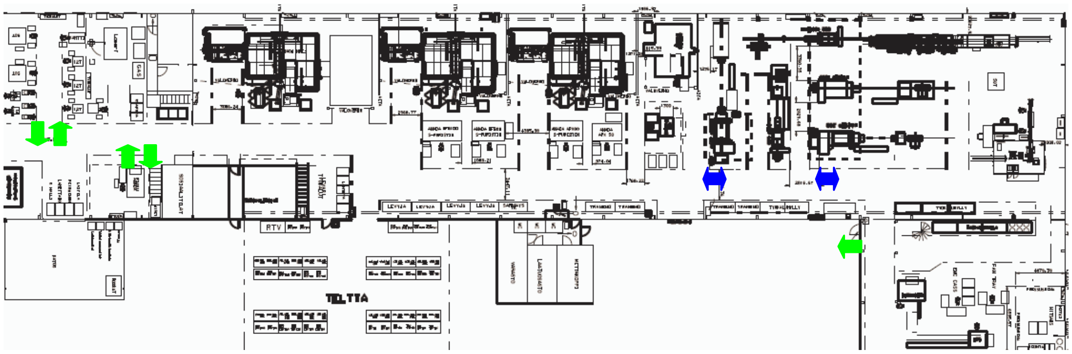


Figure 26. Close coupling sample.

The first phases were accomplished with a turret punch or progressive presses (indicated by blue arrows) and further phases took place in those areas indicated by green arrows. There may be several separated operations in the latter phase and machines are close coupled to each other. As a result of a preferred technological grouping, the first phase is far from them. Nevertheless, many close coupling solutions remained e.g. the turret punches and press brakes (figure 27.). Further, materials were also located as close as possible to their point of use (figure 28.).

Figure 27. Close coupled turret presses and press brakes.

Figure 28. Sheet metal rolls for progressive presses.

Close coupled layout was also utilized in the tool room to a far more effective extent than previously. For example, the milling machine and EDM-machines, required in tool manufacturing (figure 29.), were relocated close to the wire cutting machines to create a flow and avoid unnecessary transportation. Electro Discharge Machining is often the only suitable method for the machining of small holes and shapes into hardened steel and is a manufacturing process where material is removed from the work piece through a series of rapidly repeating current discharges between two electrodes [30].

Figure 29. Milling and EDM-machines.

9.2.2 Flow

A continuous flow system, especially single-piece flow, is the most desirable feature in lean production and the so called pull system, is the most useful. However, its corollary, the push system, is not excluded and it is only a question of decision which is preferable, since the choice of either 'pull and push' is simply who is to give the signal for operation to deliver [14]. This is shown in figure 30.

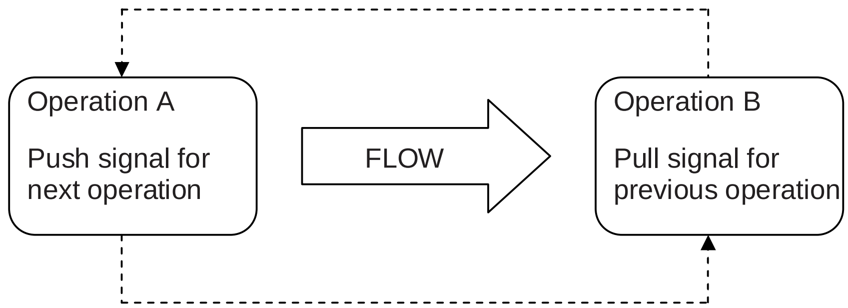


Figure 30. Push and pull signals in connected operations.

Such connected operations and continuous flow were successfully achieved in case 2., and for both cases, were indeed the very first attempts to create flow, rather than functional methods. However, traditional manufacturing still remains as the dominant system and more work is required, but for the project its first experiments are made and the layout is now more flexible for future activities.

9.2.3 Generic cells

As previously given (chapter 6.2.), generic cells were discussed and strongly recommended by Mr. Brown. However, arising from a lack of resources unfortunately this subject was not fully examined. Such solutions require far more input from engineering, than was available during the project.

However, the manual presses section may be considered as such. It has features of mass customization and is capable to produce many variations of similar products e.g. mainly parts for front assembly. Its main technology is pressing, but bending and tapping is undertaken, too. The traditional stamping method enables extension by tool design enabling e.g. forming, stamping and deep drawing. In any case, it is based on technological grouping, rather than generic product families.

9.2.4 Flexibility

Functional production is usually very flexible and the transference of this feature into e.g. line production, is a challenging task. The production line is designated for certain types of products or production, but can still be flexible to respond to other products that are within its range. Line production requires sufficient mass to be effective which for Salo specifically, is one challenging area. In a high-variety and high-mix production situation line production, any solutions would require more study than was possible during the project.

Nevertheless, the new layout achieved is far more flexible than that which previously operated. Heavy machinery is organized closely coupled, but the remainder can be easily and rapidly reorganized incurring minimal costs and labor when required. Two secondary projects were ongoing simultaneously, by the engineering department which brought in more flexibility for the turret and progressive presses, too. The turret punches' revolvers were standardized to reduce changeovers, and some press tools were modified to fit into more machines.

9.2.5 Future and continuous improvement

The new layout is a framework for future and continuous improvement. Case study 2. is still ongoing and its features are planned to be implemented for the remainder of the assembly work, too, and a washing line, otherwise left untouched during the project (see chapter 6.3.), is now to be under consideration as to whether this operation could be rendered redundant through use of an alternative method. If successful, this new method may be utilized for other machines, too and lubrication savings should be significant. This project is classified as a Six Sigma project at the Salo plant, which are generally large projects with a duration of several months. Statistical methods are utilized and projected labor cost savings should prove significant [14].

In respect of the turret presses, a second significant improvement project is now underway, in which engineering is developing further utilization of the shear feature, a feature which is specific for Salo, where this type of machine is not in use in other SSCI mechanical units. This project should provide savings in material consumption and increase further automation. The project is classified as a 'kaizen' one, involving continuous incremental improvements and smaller than usual Six Sigma projects [1].

An increased personnel training schedule for 2010, to include internal courses of lean thinking and principles for all personnel, has now been inaugurated by the plant manager, Mr. Johnny Nyman. The management team is fully committed and there is strong motivation to also apply lean methods to office waste as well as manufacturing activities.

10 Discussions

Overall this project has been time-consuming personally and for the people involved, too, since everyone has had their daily activities simultaneously as well. Nevertheless, it has been rewarding from the lean perspective as well as considering the economic target. The main objectives have been achieved, i.e. better utilization of the area, increased effectiveness of machinery and better flow between operations. Further improvements, such as true value stream solutions as in case studies are now more feasible to implement.

Lack of expertise in some areas, e.g. dealing with reconstruction aspects, has delayed some operations and caused avoidable expenses, perhaps. In case that such knowhow is not available in-house it is advisable to obtain it somehow. Furthermore, because a project in this extent requires intensive involvement, it is highly recommended that, at least, the project leader is full-time engaged for the project. It would very likely repay the investment.

Lean production as a method is not without its critics, though there is far more supportive literature, than not, available. Drawbacks have arisen, e.g. especially among non-engineering related researchers e.g. Christian Berggren of Linköping University and Stuart Green of Reading University. Some engineers, such as Darius Mehri who worked for three years as an engineer at a Toyota group company in Japan and wrote a book called “Notes from Toyota-land” have expressed their reservations, too [31].

Without a doubt there are definite advantages and disadvantages to lean application; however, the task of this work is not to discuss these, as in depth discussion of such is beyond the remit of this particular study. There is a plethora of literature, methods, tools etc. available and since this is like an open source for anyone to formulate and develop ideas, so that in this pursuit to be familiar with all angles of the subject it is recommendable to consult all possible references in order to come to personal conclusions. In this endeavour, current ’hot off the press’ internet resources in which there are, for example, many forums where professionals discuss these issues at length, will prove to be invaluable to seek out and study.

Most efficacious is that, despite its development in Japan through Toyota, lean is a practice free of application restrictions such as intellectual property rights et al, and fortunately available to all: e.g. no licenses nor fees, nor suchlike are required on the knowledge and methods used.

Further, although any activity (viz. employment) which is repetitive can thereby become stressful and management may be wanting etc., are not justifications to criticize the lean concept in itself. For example, the “85-rule” (see chapter 4.2.) is just such an attempt to keep otherwise stressful pacing tolerable and, for a local example is as applied in Nokia where machines operate at the maximum of only 85 % of their full capacity [32].

Indeed, if it is not working or definitions are inappropriate, the problem will likely be elsewhere e.g. incompetent process or function, or even at management level which may ignore this rule. Currently, in the traditional industrial environment, there is not any kind of agreed mechanism to avoid what could transpire to be an intolerable (i.e. ineffective) pace, at present.

Both sides of the symbiotic employment relationship i.e. both employee and employer, are often in rather a state of contrary objectives - even suspicion - rather than of trust i.e. in each side’s value and interconnected benefit, success and wellbeing. Indeed, it can be conjectured that at bottom this would appear to be more a question of culture and corporate management style and approach, than of lean itself as a method.

For instance, discipline, control and standards – which are specific to lean and Six Sigma principles - do not take account of the individual rights of labor which is, if not an expectation, then is a highly appreciated value, in developed countries. It is this drawback to the system’s application that its theory and thought may have now entered into the basis for so known ‘post-lean’ approach. For example, the aforementioned Christian Berggren has identified an alternative team work model in his book “The Volvo experience”, and Hans-Jurgen Warnecke has also presented a fractal model in his book “The Fractal Company”. Further, a group of researchers has studied bionic and holonic manufacturing and fractal factory in CSIRO, Manufacturing Science & Technology in Australia [33].

As such, as in science and any other theories, viewpoints and beliefs, nothing should be initially rejected without full acquaintance with the subject, and it is worth bearing in mind that lean is not the only solution available and its applications can still be found elsewhere, too. In the end, it is always one's own personal decision which is considered appropriate, adequate and feasible.

Indubitably this project has not only been an instructive rehearsal for the project team and those that participated in it, but also been enormously rewarding. Significantly, those cases studied and undertaken provided good examples of not only success, but also those efforts which proved unproductive, demonstrating that, naturally, it is better to prepare for such setbacks, since they will surely come, yet by which those victories then achieved, be all the more triumphant.

In conclusion, it is highly likely that this currently accomplished 'new state' will be, if not totally changed, then at minimum, likely adjusted, in a few year's time. Although it will always be a challenge to select the correct matters to improve - improvement in itself must be considered as paramount. Thus, at that time, to improve the "hit-rate" in the future, the quote from Peter Drucker [34], professor and management consultant, would seem to be most apposite to keep uppermost in mind:

"There is surely nothing quite so useless as doing with great efficiency what should not be done at all."

REFERENCES

1. Womack, J.P., Jones, D.T. & Roos, D., The Machine That Changed the World, vol. 2. New York: Simon & Schuster, 2007.

2. Kouri, I., Kilpailukykyinen tuotannonohjaus menestyksen perustana, Presentation, Helsinki, Tampere University of Technology, 9.2.2009.

3. Hussey, W., Sanmina-SCI Today, San Jose, Sanmina-SCI, 2008.

4. History. Available at: http://www.motorola.com/staticfiles/Business/Corporate/US-EN/history/history-home.html, 2.9.2010

5. Article 303050. Available at: http://www.arvopaperi.fi/uutisarkisto/article303050.ece, 27.7.2009

6. Sanmina-SCI Corp Form 10-K, Annual Report 24.11.2008. Available at: http://files.shareholder.com/downloads/SANSCI/689998363x0x269282/2E5294D4-594D-4617-89D9-B8843445B7F4/2008AR.pdf, 27.7.2010

7. Corporate Backrounder. Available at: http://sanmina-sci.com/pressroom/corp_back.html, 2.6.2009

8. Liker, J.K., Choi, T.Y., Toyotan toimittajasuhteet, article. Available at: http://www.mr-keskus.com/Ulista.html, 2.9.2010

9. Seppä, K., Interview, employee of SSCI 1964-2009, Salo, 5.6.2009

10. Nyman, J., Salo Plant Manager's Presentation, Salo, 10.3.2010.

11. Article, Amerikaner köper Segerström & Svensson. Available at: http://www.affarsvarlden.se/hem/nyheter/article248866.ece, 2.9.2010.

12. Alatalo. H., Interview, Engineering Manager of Salo, Salo, 14.12.2009.

13. Berggren, C., The Volvo Experience: Alternatives to lean production in the Swedish auto industry, vol. 2. Basingstoke: The Macmillan Press LTD, 1994.

14. Liker, J.K., Meier, D., The Toyota Way Fieldbook, New York: The McGraw-Hill Companies, 2006.

15. Thomes, H.M., Lean Roadmap, the Lean Leaders Guidebook, USA, Lulu Press, 2005.

16. Soronen, O., Massaräätälöinti asiakasmyötäisessä tuotannossa, Saarijärvi: MET, 1999.

17. Ford, H., My Life and Work, Akasha Publishing LLC, 1922.

18. Landes, D.S., Dynastiat, Keuruu: Otava, 2006.

19. History. Available at: http://www.toyotageorgetown.com/history.asp, 2.9.2010.

20. Piiroinen, M., Article. Available at: http://www.tekniikkatalous.fi/duuniauto/article345755.ece, 2.9.2010.

21. Taylor, F., The Principles of the Scientific Management, New York: Norton, 1967.

22. Article, Tekniikka ja Talous 4/2010.

23. Haverila, M.J., Uusi-Rauva, E., Kouri, I., Miettinen, A., Teollisuustalous, vol. 5.,Tampere: Infacs Oy, 2005.

24. Ortiz, C.A., Kaizen Assembly: designing, constructing and managing a lean assembly line, Boca Raton: CRC Taylor & Francis, 2006.

25. Samson, D., Interview, SSCI Corporate Project Engineer, 19.2.2010.

26. Ponce, S., Lean Transform Roadmap Presentation, San Jose, Sanmina-SCI, 2008.

27. Allen, C.R., The Instructor, the Man and the Job, United States: J.B. Lippincott Company, vol. 4, 1919.

28. Seretin, L., Interview of professor and researcher Mikael Sallinen, "Vuorotyö verottaa terveyttä", Available at: http://www.metalliliitto.fi/portal/suomi/ahjo_verkkolehti/?a=getArticle&issueId=63&articleId=773, 18.2.2010.

29. Hobbs, D.P, Lean Manufacturing Implementation, Boca Raton, J. Ross Publishing inc. 2003.

30. Höök, T. Article. Available at: http://www.valuatlas.fi/tietomat/docs/machining_sink_EDM_FI.pdf, 10.10.2010.

31. Miller. J., interview. Available at: http://www.gembapantarei.com/2006/05/interview_with_darius_mehri_author_of_notes_from_toyotaland.html, 10.10.2010.

32. Kaarima, J., consultant and former manager of a trial production line at Nokia, Personnel training session at Salo 22.9.2010.

33. Tharumajah A., Wells A. J., Nemes L., A comparison of the bionic, fractal and holonic manufacturing concepts. Summary available at: http://www.informaworld.com/smpp/content~db=all~content=a713805041~frm=abslink, 10.10.2010.

34. Drucker, P.F., On The Profession of Management, Boston, Harvard Business School Publishing, 1998.

Figures 1-3., http://quote.morningstar.com/stock, 23.5.2010.

Figure 4., http://www.gettyimages.com/detail/2695792/Archive-Photos, 23.5.2010.

Figures 5-30. and table 1. by the project team.