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Joel SCHEDIN[1*]
Natalia SVENSSON HARARI[1]
Mats JACKSON[1]
Mats DELERYD[1]

MANAGEMENT OF NEWNESS IN AN ASSEMBLY SYSTEM

The need for new products to suit differentiated customer needs and shorter product life-cycles, forces manufacturers to change or modify products and production systems at more frequent intervals. The objective of this paper is to discuss management of newness within assembly system design in the vehicle industry. Based on a case study covering four assembly development projects, a model using the quality concept of "7M" is presented to evaluate the level of newness. The results show that the model provides a promising platform for evaluation of newness.

1. INTRODUCTION

Today´s business environment is dominated by rapid change and global competition. Due to globalisation, demands and expectations from customers on manufactured products have increasingly become diversified and sophisticated and technological breakthroughs create opportunities for new products and new production systems. This is well summarised by the World Economic Forum [1] which state that; "In the 21st century manufacturing environment, being able to develop creative ideas, addressing new and complex problems and delivering innovative products and services to global markets will be the capabilities most coveted by both countries and companies".

Due to the current competitive environment there is a general trend in industry, e.g. within the automotive industry, towards decreasing product life cycles with a diminishing window of opportunity for each newly developed product [2]. Also, if companies in parallel with this are facing higher quality expectations and increasing pricing pressure, they have less time to improve quality, and manufacturing productivity during product development [3]. This gives a smaller margin of error and new vehicle introductions which cannot result in a drop in vehicle quality [3].

In summary, being able to get high volumes of quality-assured products to the market rapidly and at low cost is essential for competitive success [2].

[1] Mälardalen University, Sweden
[*] E-mail: Joel.Schedin@mdh.se

Winkler, Heins, and Nyhuis [4] mention that the need for an increasing range of new products and variants to suit differentiated customer needs and ever-shorter product life-cycle, requires that manufacturers have to change or modify products and production systems within the manufacturing process at ever more frequent intervals. Further Yamamoto [5] highlights that production functions, especially those located in high-wage countries, must be proficient in radical innovation within production and be capable of creating new knowledge and constantly developing and implementing radically new production technologies, processes, and equipment which make their production systems more “unique”.

With an increase of modified and/or new products as well as production systems being developed at more frequent intervals, it is interesting to reflect on how companies effectively and efficiently can manage this. One way to study this phenomenon, which has been defined and described from several perspectives in different contexts, is to look upon how industry manages the degree of newness and novelty in a product and a production system during the product realisation process. The importance of newness and novelty in products has been analysed and described in literature. The question *what is “New” about a new product?* was researched already in the 1960ths [6] and for example studies have been made on the influence of product design newness on sales performance across a product’s life cycle and results emphasize that both design and technical newness are important drivers of car sales [7],[8]. According to Salomo et al. [8], for management practice, these findings suggest to clearly define objectives for product innovativeness, which can guide new product development and to deliberately strive for higher degrees of newness. However, as Garcia and Calantone [9] also highlights, little continuity exists in the new product literature regarding from *whose* perspective this degree of newness is viewed and *what* is new. In addition to this situation, further potential have also been identified regarding the need of evaluating newness and novelty dimensions on more detailed sub-levels [10].

This theoretical gap is also supported by the same need identified from a high management level in one of the largest manufacturing companies in the heavy duty vehicle industry. The company searches for a practical tool for management of newness related to their production system development. In order to create a possibility to contribute within this area, the objective of this paper has been to discuss management of newness with a specific application of assembly system design in the vehicle industry.

The method selected to investigate this phenomenon is retrospective case studies focusing on a plant within the heavy duty vehicle industry in Sweden, where four assembly lines for different variants of one complex sub-component were in focus. Each assembly line was developed, implemented, lean transformed and used for full scale production during the last nine years.

Data was collected from active participation in the projects, review of documents, studies of physical artefacts and interviews with key persons in the cases. A model has been created with inspiration from theory using the quality concept of “7M” and it is presented to evaluate and describe the level of newness. The results from each case are visualised with the use of the model and a number of aspects have been of special interest related to evaluating newness from an assembly system perspective.

2. LITERATURE REVIEW

This paper has a focus on newness from a production and assembly system design perspective and the following definition and description from Griffin [11] is relevant in this context;

> *"Project newness is the amount of change, expressed as % new or % different, induced into the product and manufacturing process between the last generation product (if applicable) and this one"..."Since the focus here is on the firm's development cycle, the amount of change measured is actual engineered change to the product or manufacturing process, not the amount of change visible to the customer"..."For manufactured goods, changes have been calculated by comparing the bills of materials for the new product to the bill of materials for the previous generation product".*

Not all components in a new product are equal in complexity and a definition by Pufall et al. [12] of product novelty related to this fact is the percentage material value of physical components that is new to a responsible development center, compared with previous products that have already been developed at the development center. Worth to notice is that a relatively small change in the product really can have huge impact in the production system.

Newness and Novelty are both terms found in literature which are used in describing the same phenomenon. There exist several newness and novelty assessment models, to be used for products as well as in production systems, with different assessment scales and focus. These models are used for example when analysing carry-over solutions or analysing what may be new to the company, new to market, and also what may be new even on a global scale [13],[14],[15]. Examples of an evaluation scale for newness assessment have also been made in relation to developed design standards and in this application the newness assessment can be used for selection of various design reviews during a company's product development including level of change in manufacturing method/process as one parameter [16]. Other studies have also reflected on how the level of newness can affect the development work and the development process, i.e. in relation to use/usefulness of different tools and methods [17], concurrent engineering [18],[19] and increased newness may often be related to uncertainty and complexity [20].

Related to proactive production system development work Bruch and Bellgran [14] present an interesting proposal with an integrated portfolio planning of products and production systems including advanced engineering. They created, based on the empirical results, a model that visualises four different levels of newness in relation to advanced engineering within production system development: 1 - Use of carry-over solutions from existing or earlier production systems, 2 - Improved existing production technology solutions already known to the company, 3 - State-of-the-art production technology solutions not previously used at the company and finally, 4 - Development of unique production technology solutions [14].

There are also examples of research indicating that increased newness has an impact on the production ramp-up [12] and several authors have made contributions about newness and novelty in connection to the ramp- and start-up phase of a production system the last decades [2],[10],[21]. We find especially the work by Van der Merwe [10] of interest because there the novelty concept is mentioned to be for the first time explicitly combined with the learning concept in a conceptual ramp-up framework. He has also created very preliminary guidelines for managers who would like to use the framework as help in creating attention to generic areas of concern for different novelty dimensions [10]. For example learning response in form of pre-production learning, post-production learning, resources required (time, engineering and money) and ramp-up production impact [10].

A production system can for example include both the parts production system and assembly system [22], see Fig. 1.

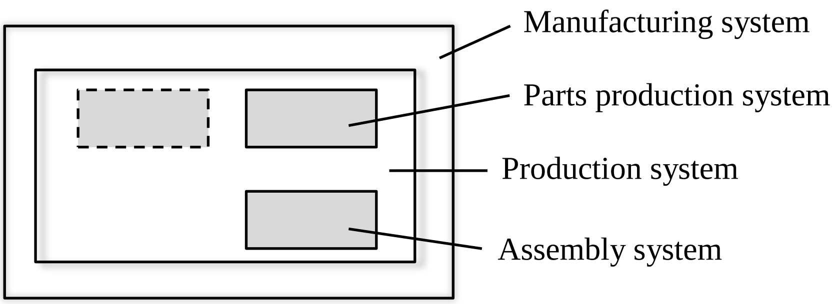

Fig. 1. A hierarchical perspective on production system [22]

Hubka and Eder [23] have presented theories and a model of technical systems which can be used to describe a production system. The production system consists of a transformation process and a number of sub-systems - human system, technical systems, information system, and management and goal system. Newness in this context of production and assembly systems has thus relations to all these constituent parts.

The concept of newness and novelty in different parts and subsystems in a production system can also be viewed from a Quality Management perspective. Causes of quality problems are often referred to and related to any of the following seven M´s: Management, Man, Method, Measurement, Machine, Material and Milieu [24]. These 7M factors are well known in industry and a similar model is used in the ISO/TS 16949 industry standard document Advanced Product Quality Planning (APQP) and Control Plan [25] that organises the types of process inputs into a cause and effect diagram, where the primary groupings are: People, Materials, Equipment, Methods and Systems, Environment and Customer Requirements. Van der Merwe [10] also uses identified ramp-up problems and specifically their causes as categories for dimensions of novelty; product novelty, process novelty, product mix novelty, supplier novelty and personnel novelty. He further describes the idea of novelty as a driver of ramp-up performance in his research, which led him to learning being identified from literature as characterising the organisation's response to novelty [10].

The findings from Van der Merwe [10] about learning as the organisation´s response to novelty is interesting in connection to principles being focused in industry for improved product development performance. For example the principle of "front-loading" and early problem solving within lean product development [3],[26] and to manage the "knowledge value stream" within a company [27].

In relation to the knowledge value stream also the insights about process management in Adler, et al. [28] that each development project involves unique challenges that need unique solutions, but there are many tasks and sequences of tasks that are the same. This probably enables that the management of newness and novelty can continuously be improved through i.e. standardisation [29], product development value stream mapping [30],[31] and organisational learning [32].

To summarise the literature above, current theories indicate that research regarding newness and evaluation of newness in both products and production systems are available. This paper concludes that newness from a production system perspective should be connected to the different constituent parts of the production system, and could be divided into four different levels of newness; carry-over of existing solutions, improvements of existing solutions, implementation of existing state-of-the-art solutions, and the development of unique solutions. As discussed in the paper, the production system consists of different parts and subsystems that also should be evaluated based on their respective level of newness. Based on the discussion above, a proposal of a model to evaluate the level of newness in an assembly system using the quality concept of "7M" is presented in the next section.

3. MODEL SUPPORTING EVALUATION OF NEWNESS

With the insights from the theory presented above in relation to the standard ISO/TS 16949 and Advanced Product Quality Planning (APQP) and Control Plan [25]: "*The key to successful development of cost effective processes is identification of the sources of variation and appropriate control methods"* we have created a model to evaluate newness and novelty within assembly systems, see Fig. 2.

The model is based on the selected Assembly System Newness Levels adopted from Bruch and Bellgran [14] with an optional focus from a plant perspective and not only on technical solutions. The Dimensions selected are the 7M from Bergman and Klefsjö [24]. The clear line of the Start of production is related to what learning that need to take place pre-production from Van der Merwe [10]. An Early Assembly System Newness Assessment supports the lean principle about "front-loading" [3] and the development of Processes to each dimension and newness level can be related to Adler, et al. [28] with recurrent tasks across several projects.

The idea is to evaluate newness in relation to what is needed to be in place at start of production of an assembly system, which would give prerequisites to perform actions and conduct activities trying to avoid problems at start of production. Such a model or tool would be valuable within assembly system design and the results could be used for a proactive development work;

1. Performing activities within assembly system design with focus on securing start of production – efficiency (doing things right).

2. Establishing a process securing continuous work and continuous improvements within assembly system design.
3. Reflecting on the results and challenges within the different dimensions regarding newness with impact on effectiveness in the development work (doing the right things).

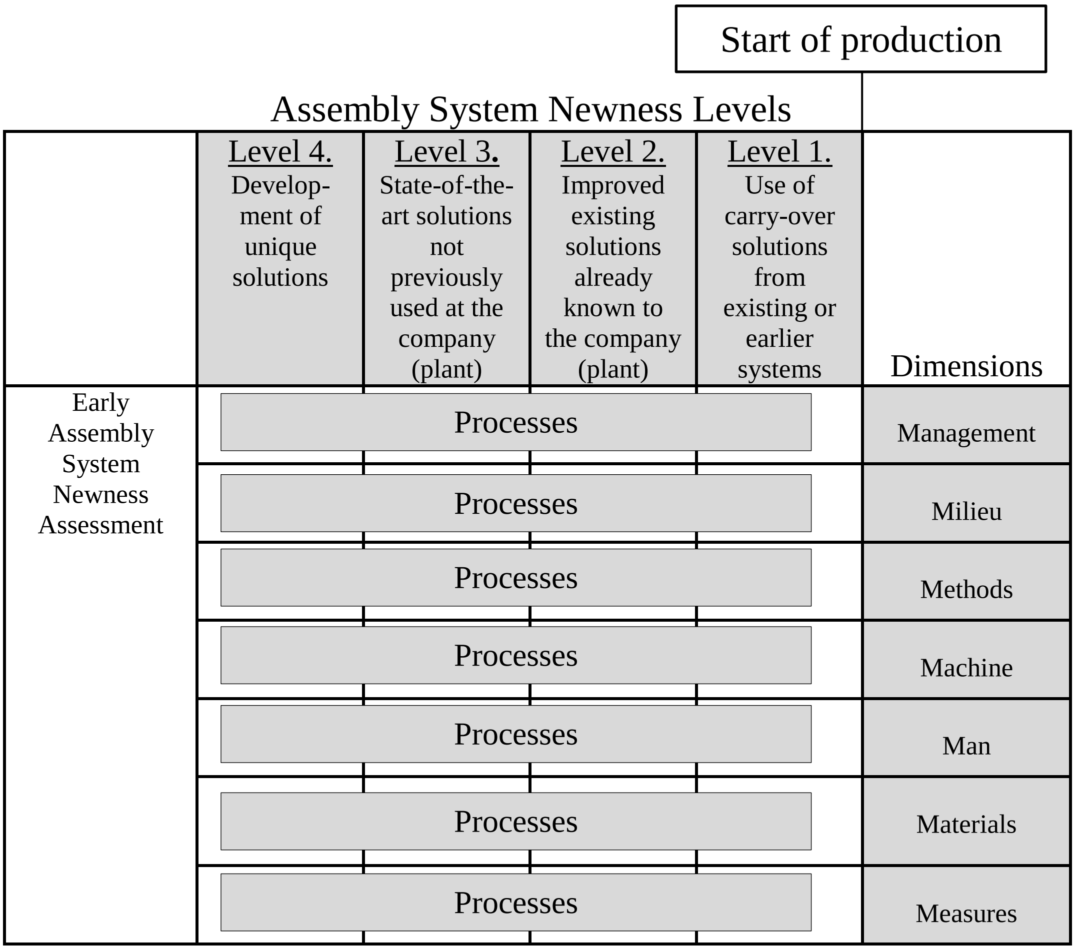

Fig. 2. Model supporting the evaluation of newness and novelty within assembly

4. METHOD

To further investigate and analyse newness within assembly system design, as well as the proposed model, a retrospective case study has been conducted. A case study is a preferred research method when a specific phenomenon is to be closely studied within its natural context [33]. Case studies can be characterised by the fact that they often study a phenomenon when and where it happens and that the exact context or delimitations are not fully known [33].

The motivation for the retrospective study and selection of the cases was the rare opportunity from first hand experiences of the development, implementation, lean transformation and full scale production of four assembly lines at one of the largest heavy vehicle companies. A typical example of an assembly line studied during the cases is showed in Fig. 3. One author worked as assembly engineer during the first two cases. Followed by a role as project manager for the assembly line development and installations in the third and fourth case, and finally also working as a lean coach during the transformation in the fourth case. Another author involved was Safety, Quality and Environmental manager for the whole company.

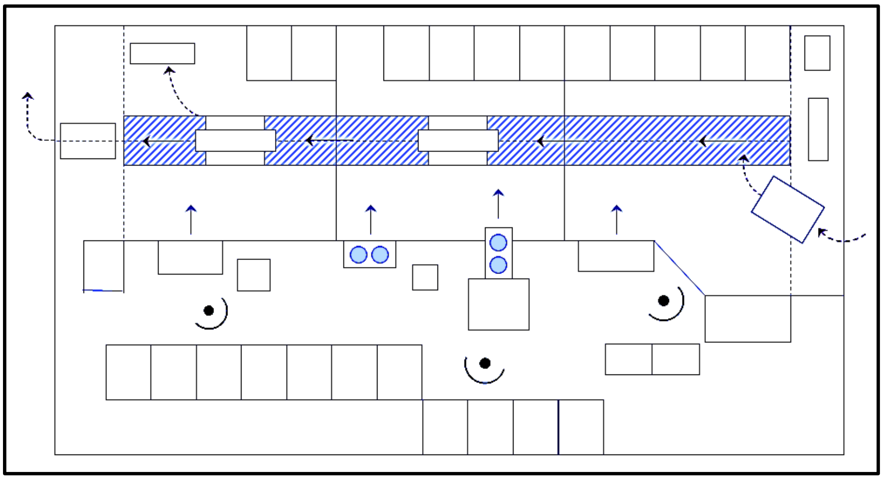

Fig. 3. Assembly system layout in Case 1

The research process used is further described below, see Fig. 4.

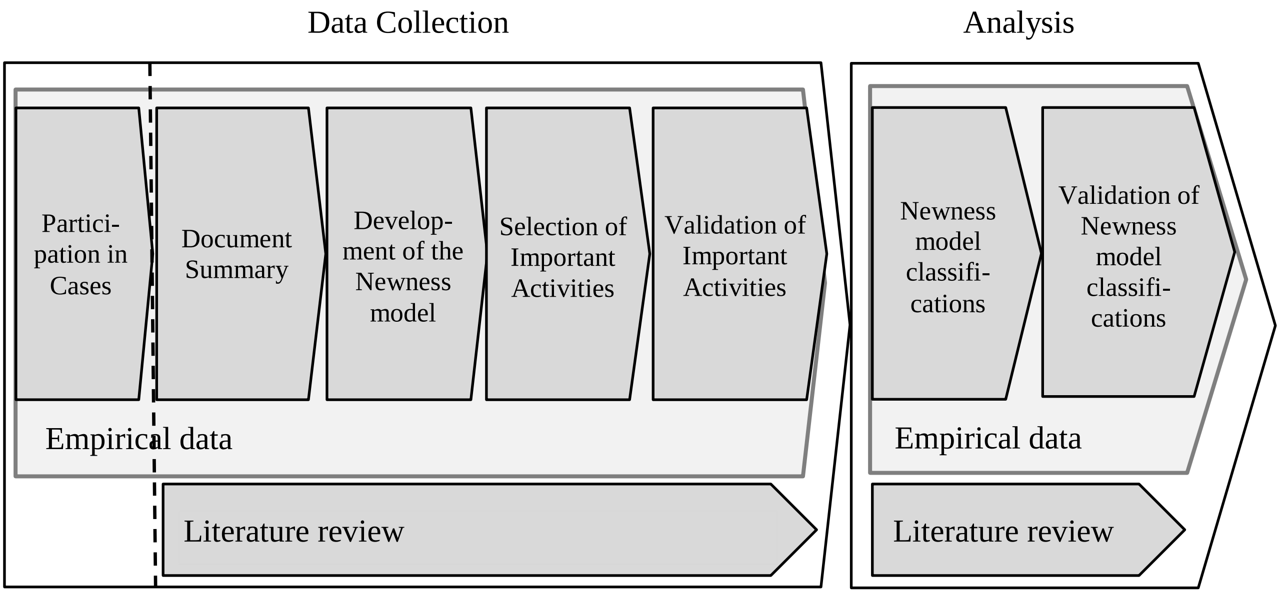

Fig. 4. The research process used in this paper

The assembly systems studied are still in use at the company for their full scale production and the total calendar time for the development, implementation and lean transformations of all four lines was about three calendar years. Each assembly line was developed for different variants of the same type of complex sub-component for heavy duty vehicles. Case 1 was a new assembly line for existing products, in total nine unique variants; Case 2 was a new assembly line for completely new products, in total six unique variants. Case 3 was a new assembly line for existing products, in total nine unique variants and Case 4 was a new assembly line for both modified and existing products, in total eleven unique variants, in which eight were modified. The product architectures and the production volumes were different for all four assembly lines. The configurations of the assembly lines in the cases were one manual final assembly line with between 2-7 stations, complemented by pre-assembly stations in direct connection to the line in order to create pull systems with a visual flow [34], see for example Fig. 3. Assembly system layout in Case 1. There was one assembly worker per station at the final assembly lines and a fixed pace used at each line.

Participation phase: Data and experiences were collected during participation in the cases and the different roles in the organisation of the authors enabled triangulation.

Document Summary: A retrospective collection of 13 project binders from the work in the roles as assembly engineer, project manager, and lean coach was done. The binders covered documentation of different project activities and a summarisation of the Table of contents in the binders were made in excel by the author owning the binders. In total 217 numbers of headings to summarise activities from the cases.

Development of the Newness model: Based on experiences from the cases, the document summary and a literature review the model supporting the evaluation of newness and novelty within assembly were created, see Fig. 2.

Selection of important activities: Based on a project evaluation report and experiences from the participation phase a selection of significant project activities for each of the four cases was made and summarised in excel. The selected important activities were divided into three categories to describe: first briefly what was done per case, secondly a description of what was new and finally a description of what was critical.

Validation of Important Activities: The selected important activities were then validated with one key actor from each of the cases during an interview. From the first case an assembly engineer was selected and from the second a person contributing full time from the assembly department. For the third and fourth case the same person contributing full time in both those cases from the assembly department was selected. All interviews were recorded and in the second and third interview the participants were also asked to mark the document in colour whether they agreed fully, partly or disagreed with each significant activity.

Newness Model Classifications: The evaluation procedure for the classification of newness was of qualitative order in two steps.

First the selected important activities categorised as new or critical were further classified in relation to the different “7M” Dimensions in the model. For a lot of activities, several classifications were possible and each activity was classified in relation to their most dominant dimension match. As an example new hydraulic test equipment was classified into the dimension Measures, even when the dimension Machine also should have been possible, see Fig. 6. This classification of each activity into a dimension was made by the author that has been working as an assembly engineer in the first two cases and project manager for the second two cases, based on experience.

As the second step each new activity per "7M" Dimension was evaluated in relation to the four Assembly System Newness Levels in the model**.** The base for the evaluation was the detailed experiences one author had from earlier and existing assembly systems in the plant. Both from work as an assembly engineer and being the responsible production engineer for parts of the existing assembly system during more than one year. In addition to the work as an assembly engineer in the first two cases and project manager for the second two cases.

Evaluation Standard

The Assembly System Newness Levels were classified based on the situations in the existing and earlier assembly systems in the plant before each of the new assembly lines and pre-assembly stations were developed and installed.

- Newness level one included carry-over solutions, i.e. was a specific nut runner moved from the existing assembly system to the new line in Case 1.
- Newness level two was used when known solutions from existing or earlier assembly systems in the plant were improved, i.e. was a roller conveyor on a press modified in order to decrease its size on the line in Case 1.
- Newness level three was used for new solutions, not used in the existing assembly systems in the plant, aimed to be at state-of-the-art level based on i.e. benchmarks, supplier- and consultancy experiences and literature. For example a new live roller conveyor was implemented in Case 4.
- Newness level four was used if the solutions didn't existed before and the company and/or suppliers had to develop completely new solutions, i.e. new presses were developed together with suppliers in order to enable efficient and quality assured assembly of a new product in Case 2, see Fig. 5.

<u>Validation Newness classifications:</u> For each of the newness model classifications data was collected to validate the results, in the form of documents and photos of the solutions at the new assembly lines in all four Cases. Also documents and photos supporting the critical factors (7M) were collected.

5. ANALYSIS

Table 1 visualises how the proposed model has been used to evaluate the level of newness in the different assembly system design projects based on the selected important activities from the cases. The areas marked grey under Assembly System Newness Levels indicate that a dimension of newness has been identified in the respective cases. The areas marked grey in the additional column “Critical factors (7M)” show critical factors, categorised in relation to the different dimensions in the respective cases. For each case a Validation of the Newness Classifications was also made, including as an example photos of new unique press equipment developed together with suppliers and classified in the model as 7M Dimension “Machine” and “Assembly System Newness level 4” in Case 2, see Fig. 5. Another example is the Hydraulic test equipment in Case 2 classified as 7M Dimension “Measures” and “Assembly System Newness Level 2” in Fig. 6.

Fig. 5. New press equipment in Case 2 classified as 7M Dimension Machine and Assembly System Newness Level 4

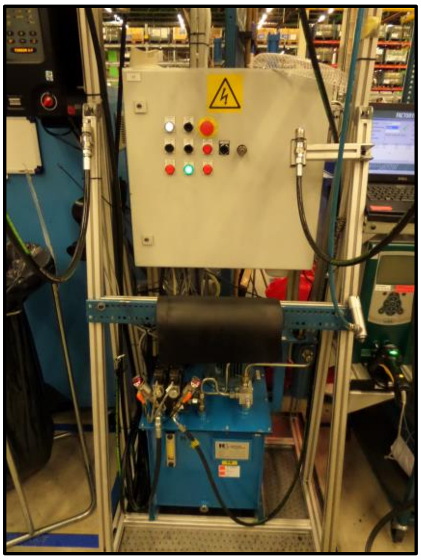

Fig. 6. Hydraulic test equipment in Case 2 classified as 7M Dimension Measures and Assembly System Newness Level 2

Table 1. Retrospective evaluation of newness within assembly based on the selected important activities from the cases. The areas marked grey under Assembly System Newness Levels indicate that a dimension of newness has been identified in the respective cases. The additional column "Critical factors (7M)" show critical factors found

Case 1

	Assembly System Newness Levels: Level 4. Development of unique solutions	Level 3. State-of-the-art solutions not previously used at the company (plant)	Level 2. Improved existing solutions already known to the company (plant)	Level 1. Use of carry-over solutions from existing or earlier systems	Dimensions	Critical factors (7M)
Assembly System Newness Assessment - Retrospective Example, Case 1		■			Management	■
				■	Milieu	■
		■	■		Methods	■
	■	■	■	■	Machine	■
				■	Man	■
					Materials	
					Measures	

Case 2

	Assembly System Newness Levels: Level 4. Development of unique solutions	Level 3. State-of-the-art solutions not previously used at the company (plant)	Level 2. Improved existing solutions already known to the company (plant)	Level 1. Use of carry-over solutions from existing or earlier systems	Dimensions	Critical factors (7M)
Assembly System Newness Assessment - Retrospective Example, Case 2					Management	
			■		Milieu	
	■				Methods	
	■		■		Machine	■
	■				Man	■
					Materials	■
		■	■		Measures	

Case 3

Assembly System Newness Levels

	Level 4. Development of unique solutions	Level 3. State-of-the-art solutions not previously used at the company (plant)	Level 2. Improved existing solutions already known to the company (plant)	Level 1. Use of carry-over solutions from existing or earlier systems	Dimensions	Critical factors (7M)
Assembly System Newness Assessment - Retrospective Example, Case 3					Management	
					Milieu	
					Methods	
					Machine	
					Man	
					Materials	
					Measures	

Case 4

Assembly System Newness Levels

	Level 4. Development of unique solutions	Level 3. State-of-the-art solutions not previously used at the company (plant)	Level 2. Improved existing solutions already known to the company (plant)	Level 1. Use of carry-over solutions from existing or earlier systems	Dimensions	Critical factors (7M)
Assembly System Newness Assessment - Retrospective Example, Case 4					Management	
					Milieu	
					Methods	
					Machine	
					Man	
					Materials	
					Measures	

Examples from the cases of newness found in the assembly system in relation to the different Dimensions and Assembly System Newness Levels are further discussed below. In addition critical factors are also exemplified.

Management

Case 1 was a pilot project for the implementation of lean production management strategies and principles in the assembly at the plant. Therefore, categorisation newness level three, state-of-the-art solutions not previously used at the company (plant) was selected. This had impact on strategies (i.e. implementation of two-shifts), as well as direct impact on the development of the assembly line. Critical factors related to the development and implementation of lean production in the assembly system was support from experienced consultants with knowledge, methods and earlier experiences. Another critical factor in Case 4 related to management was postponed dates in the time plan for the implementation of the line in order to reduce risks in addition to that small parts of the line was implemented and verified piece by piece.

Milieu

All the selected important activities in the cases about milieu were related to implementation of the lines on new or modified assembly areas within the existing plant. In Case 2 one categorisation was also higher ranked as newness level two, an improved existing solution already known to the company (plant), due to improved lightning for the assembly workers on that line. This solution was later also implemented on all lines, but then categorised as newness level one, use of carry-over solutions from existing or earlier systems, in the other cases. A critical factor related to milieu was that the implementation of the assembly line in Case 1 was finished according to plan because its former area was going to be rebuilt for a part-production cell.

Methods

A significant newness in relation to methods was found in Case 2 which included newness level four; development of unique solutions due to the product design of a completely new product. Further, in Case 1 a new method which included state-of-the-art solutions not previously used at the company (plant) for an existing assembly sequence was implemented and that was found critical (for an internal customer) from a quality perspective before it was fully calibrated for all the products on the assembly line. Finally, in Case 1, 3 and 4, the new assembly line layouts were categorised as newness level two, improved existing solutions already known to the company (plant), based on the motivation that the plant had used assembly line concepts before they used station assembly. In Case 4, same methods, but a new assembly sequence and line balancing were also motivation for applying the second level newness categorisation.

Machine

Two examples of newness level four, development of unique machine solutions, were found in Case 1 and Case 2. These were examples of nut runner and presses. Those solutions were developed in close cooperation with equipment suppliers. Nut runners were also purchased in order to improve safety and to assure available back-up solutions mentioned as a critical factor in Case 1, and to improve quality and safety on newness level two in Case 3 and newness level three in Case 4. Material handling equipment as live roller conveyor in Case 4 and new material racking’s, packaging and logistic solutions in Case 1 were also examples of newness level three. Safety approval of new material handling equipment was highlighted as a critical factor in Case 3. New Information system was another example of newness level three in Case 1. New line layout in Case 2 and a modified press in Case 1 where examples of second level of newness. Equipment was also reused in Case 1 as an example of newness level one and in relation to this a critical factor mentioned in Case 4 was that a lot of presses weren't purchased as first planned, instead current equipment was moved and reused. From Case 2 other highlighted critical factors were also late implementation of the assembly line and improvement potential regarding preparation and test of the complete production system including personnel (with test of full pace production) before start of serial production.

Man

The newness level four was found in Case 2 where the assembly workers had to assemble completely new products. This was also related to a critical factor in Case 2 regarding insufficient education for the assembly workers, which resulted in wrong parts being assembled and delivered to an internal customer. In Case 1, Case 3 and Case 4 a newness level one was related to current assembly workers. Finally, mentioned as critical factors in relation to man was the lack of practical experience from lean production in large parts of the organisation in Case 1 and the help from consultants within production engineering for capacity reasons in Case 3 and Case 4.

Material

Fault in the material from a supplier was found as a critical factor in Case 2. Consequences affected both internally and also as a campaign in the field.

Measures

New measurement equipment was categorised as newness level three in Case 2 with an aim of a fixed assembly sequence including poka-yoke systems [34] in presses. Modified and new test equipment was also categorised as newness level two in Case 2.

6. DISCUSSION AND CONCLUSIONS

The objective of this paper has been to discuss management of newness with a specific application of assembly system design in the vehicle industry. This has been done based on a development of a model aiming to support the evaluation of newness and novelty within assembly systems. Newness is defined based on the different constituent parts (dimensions) of the production system, and could be divided into four different levels of newness; carry-over of existing solutions, improvements of existing solutions, implementation of existing state-of-the-art solutions, and the development of unique solutions.

The proposed 7M dimensions in the model have shown to be practical based on the findings in the empirical cases. The Assembly System Newness Levels showed potential for visualisation of newness related to different levels of challenges based on the empirical examples. The combination of the 7M dimensions with the assembly system newness levels in the model can also be seen as an academic contribution related to the need of evaluating novelty on a more detailed/sub–dimensional level as discussed by for example Van der

Merwe [10]. The need of pre-production learning before the Start-of-production in the assembly system has also been exemplified.

One question regarding the model is whether there are important rules, connections and relations to be used as guidance between different high levels of newness found in parallel in different dimensions? For example on how the relationships between methods, machine and man found in Case 2 can guide the approaches to achieve wanted quality assurance levels in the most effective way. The dimensions in the model can perhaps act as a structured complement to the overall assembly system design processes that also take more general project aspects into consideration.

Based on the summary of data, from experiences and from the validating interviews with key persons, it was confirmed that implementing newness in the assembly system can have both a negative and a positive contribution on company´s performance. For example the number of internal customer claims was reduced by the implementation of new measurement equipment and number of field problems by new nut runners. Based on this we want to encourage companies not to see high level of newness only as something risky and negative, rather to try to take advantage of new opportunities, and to create competitive advantages by learning how to handle high levels of newness in an effective and efficient way.

To support an overall research goal of creating a validated tool for management of newness in assembly and production systems this paper concludes:

- In this study examples of new and modified content related to assembly system design in the vehicle industry have been exemplified from an empirical case study at a company in Sweden.
- Based on a case study covering four assembly development projects, a model using the quality concept of "7M" is presented to describe the level of newness. The results show that the model provides a promising platform for evaluation of newness from a specific assembly system perspective.
- Finally, management of newness with a specific application of assembly system design in the vehicle industry is also discussed.

Even if the findings in this paper contributes to the identified need of evaluating newness and novelty dimensions on more detailed sub-levels, it is important to notice that this study was done only at one plant in one company in Sweden and the examples are from different variants of the same type of complex sub-component for heavy duty vehicles. This put clear limitations to the possibility to generalize the results. From a methodological standpoint the selection of retrospective case studies and the focus in the analysis on mainly the Dimensions and Assembly System Newness Levels also eliminated the opportunities to fully evaluate empirically all the different parts of the model. However, the value of the detailed insights from the authors participating work was considered of higher value to motivate this risk. The findings in the paper shall be looked upon as a first pilot test of the model and it is important to see the findings from the cases only as first examples that have showed a first promising potential.

There are several needs for further research identified from this study e.g. to answer how each newness dimension in the best way could be assured and how the continuous improvement process during and between projects related to newness shall be done. Related to this it was mentioned in one of the validating interviews that further improvements still can be made today at the plant regarding implementation and test of the assembly system at full pace before Start-of-production. Further research is also needed about the Early Assembly System Newness Assessment part of the model.

Another area is to investigate the dimensions in relation to the assembly system newness levels and the other parts of the model in other contexts. For example in relation to assembly systems in different plants, companies and industries, in addition to assembly of different components, complete vehicles and different levels of assembly system automations. It should also be interesting to see if the model is valid for parts production.

A quantitative study related to assessment of newness when introducing new products in an assembly system would be of interest and also to further investigate in which way the degree of newness in the assembly system affects needed resources (i.e. time, cost and competences), especially in relation to methods and learning for quality assurance of each of the dimensions. Finally, how management of newness in a production and assembly system preferably should be implemented into a company's product development and production system development processes for practical use, would be of high interest.

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