Assembly Tasks in the Automotive Industry: A Challenge for Older Employees

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Lessons Learned

It appears that the demographic problems reported in the Daimler-Motorengesellschaft in Stuttgart-Untertürkheim 100 years ago (Schumann 1911/2011) can still not be considered solved by empirical social research today. Schumann writes,

> Peak workability is reached at the age of 35. By the age of 45, workers are already having trouble finding employment. Short sickness leaves occur frequently. The influence of piece-work tasks on mental and physical strain during work is distinctive (p. 146f).

Growing physical complaints among older employees, the considerable increase in standardised processes, the partial decrease in task diversity and autonomy, and short cycle times all make it difficult for employees in assembly lines to remain healthy and active until they reach the legal retirement age. If this socio-politically meaningful goal is to be pursued in terms of age-based working conditions in automotive assembly, the following measures, which are based on the findings of the given project, should be taken into account when planning and implementing interventions:

- Ergonomic design of work equipment (standing/sitting workplaces, height-adjustable assembling tables and platforms, assisting systems for lifting and

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carrying weights, etc.) and surrounding conditions (noise, lighting, temperature, etc).

- Systematic alternation of physical strain through the combination of value-adding tasks (for example, assembling by hand) and non-value-adding tasks (material provision, maintenance, core figures, etc).
- Consideration of each individual's abilities during competence development, work design and work organisation.
- Longer, non-cycled assembly processes and individually adaptable work speed and work rhythm.
- Participation-oriented design of work conditions and work processes.
- Development of a human resource management strategy that is person-oriented while still taking into account standardised processes.

By incorporating these criteria during the development of sustainable assembly concepts and systems and adopting a person-oriented view of the manufacturing processes, we can preclude the simple continuance of integrated production systems and assure employment of older persons.

Older Employees in the Automotive Industry: Conceptual Framework and Derivation of Central Research Questions

The automotive industry is a key industry in Germany and one that faces high competitive pressure at the international level. It employs approximately 400,000 people, with another 300,000 persons working in the automotive supply industry (see VDA 2011). A substantial percentage of these persons are involved in assembly tasks.

Between 5.4 and 6 million cars were assembled in Germany between 2006 and 2011. The entire world market produced approximately 64 million cars in 2010. The greatest growth in the automotive industry can be noted in Brazil, Russia, India and China (BRIC states). The production capacities of all automotive-producing countries combined are estimated at roughly 100 million vehicles per year (Wimmer et al. 2010).

The number of employed persons in the German automotive industry has only shown slight growth. Take VW as an example: Between the years 2006 and 2010, the number of VW employees in Germany rose from 174,000 to 178,000, while employee numbers at foreign production sites increased from 155,000 to 210,000. This trend developed further in 2011, providing evidence that the plants abroad employ a great deal more people than the German plants.

During the peak of the economic crisis in 2008 and 2009, the German automotive industry attempted to prevent lay-offs by granting older employees (55 years and up) tax concessions in conjunction with partial retirement models. For instance, 5.9 % (2008) and 4.5 % (2009) of BMW's German workforce opted for partial retirement in 2008 and 2009 (see BMW Annual Report 2011).

The average age of permanent employees in the German automotive industry varies between 40 and 48 years. Most of them are male (women make up only about 10–14 % of the workforce). The number of temporary staff and contract workers is rising, as is the number of employees who are retained by means of work contracts. In some assembling domains as much as 30 % of the workers are on a temporary contract, and in exceptional cases the percentage is even higher. In company agreements (between the management and the work council), quotations can be found in which temporary and contract workers make up 3–8 % of the overall workforce.

In addition to these economic conditions, the German and the international automotive and components supply industry has been copying and adapting the Toyota production system over the past 10 years. According to Jürgens (2007), most of the basic principles, instruments and practical routines of this integrated production system have already been introduced into German automotive plants. As far as Jürgens is concerned, Kaizen, Poka-yoke, Andon and many other Japanese terms have found their way into the operative business. However, such profound changes to the customary work structure can cause irritation among employees. Moreover, Jürgens (2007) sees a risk of succumbing to "management by stress" (2007, p. 45 and Conti et al. 2006).

The avoidance of waste [over production, buffering, needless movements, unnecessary walking, searching for parts, etc., see Ohno (2009)] is the paramount goal of value-oriented production systems. It is best achieved using the Toyota production system and can be found at nearly all German automotive manufacturers (cf. Neuhaus 2010, p. 80 ff). Some of the tools in this system are 5S orderliness and cleanliness, just-in-time logistics, total quality control, visual management, continuous improvement process, standardisation, total productivity maintenance (TPM), teamwork, process management, auditing, key figures, etc.

The implementation of these new production structures creates numerous risks in the assembly and fabrication work of the automotive industry and its components suppliers [see a more detailed report by Landau (2011)]. These include:

- Repetitive tasks with high manual operation frequencies, such as cycle times of 1 min or less.
- Enforced body postures, such as assembling inside of the vehicle interior.
- Work with increased energy/strength expenditure, such as when padding car seats.
- Utilisation of hands and arms as a tool (knocking, hammering, turning, pushing, such as when aligning parts or during clipping).
- Energy-impact/force-impact while attending to work appliances/equipment (such as screwdriver, riveting machine).
- Manual load handling (such as lifting and carrying pieces exceeding 10 kg).

These risks cause greater physical strain for older employees. That said, such working conditions ought to receive critical attention even among the younger workforce.

Employee surveys are a common phenomenon in the German automotive industry. However, their evaluation is treated as an internal matter. Systematic comparisons between individual automotive manufacturers concerning the effects of working conditions on employees engaged in assembling and fabrication are lacking, despite the fact that such data is of great importance when dealing with the impact of demographic change. The automotive industry exerts considerable influence on the work organisation of its components suppliers, so its work structures often serve as a standard for the components suppliers depending on this industry.

The present comparative study looks at two automotive manufacturers and their working conditions for components assembly (plant A) and final assembly (plant B). The object of the longitudinal study is to identify how employee attitudes toward work (tasks) differs in terms of company and point of assessment over a period of 6 years. Furthermore, their psychological and physical wellbeing is assessed in conjunction with the individual tasks carried out. How do the various work structures in the two companies affect employees during the project period? To what extent do workability and the selected psycho-physical performance parameters of employees change over these 6 years and what impact do the ergonomic measures adopted have on the employees?

Description of the Area of Research and Data Collection

Data was collected at two German automotive manufacturers (plant A and B) between 2005 and 2011 using a longitudinal study design (see Fig. 1). The study focused on aggregate assembly in plant A and final (vehicle) assembly in plant B. In plant A, various equipment assembling is considered: A1 gearbox assembly of a specific automatic gearbox, A2 handbrake lever assembly and A3 exhaust system assembly. Meanwhile, in plant B the assembly of the wiring harness is examined (see Table 1).

Simplified, the component assembly (in A1) can be described as a semi-automated assembly task (degree of automation approximately 50 %) on an assembly line. This means the employees take components (from a container), place them on

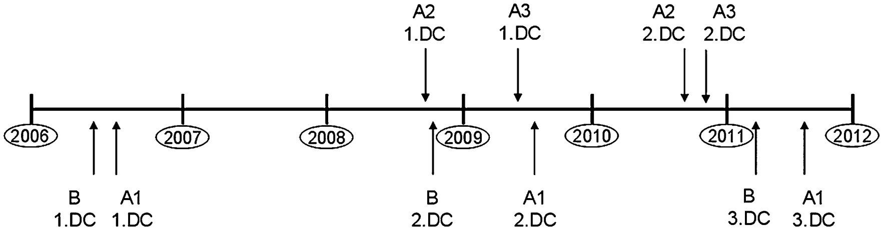


Fig. 1 Time schedule of the data collection (DC)

Table 1 Average age of persons in sample groups (in years); sample size (N)

	Cross sectional data			Longitudinal data
Data collection	1.DC	2.DC	3.DC	1.DC
Plant A1	38.2	38.8	41.3	37.5
Gearbox assembly	(N = 185)	(N = 207)	(N = 65)	(N = 19)
Plant B	38.1	40.4	40.7	36.5
Wiring harness assembly	(N = 242)	(N = 155)	(N = 110)	(N = 80)
Plant A2	32.1	36.7	–	34.4
Handbrake lever assembly	(N = 17)	(N = 28)		(N = 9)
Plant A3	41.9	42.6	–	40.3
Exhaust system assembly	(N = 22)	(N = 35)		(N = 12)

Note In the longitudinal design, the average age of the persons in sample groups increases by number of years passed between the points of 1.DC, 2.DC and 3.DC

the assembly rack or corresponding appliance and activate the process with an automatic assembling machine. The entire assembling process consists of approximately 50 cycles. The cycle time varied between 85 and 72 s from the first to the third point of data collection.

In A2, handbrake levers are installed by means of an automatic assembling machine. The entire assembling process consists of two cycles, each with a duration of roughly 25 s. The assembling process is based on the Chaku–Chaku–principle (see Kono 2004; Yagyu 2007): the employee sequentially operates two or three workstations by placing parts, activating the machining process, removing the component and placing it in another machine. In A3 exhaust systems are welded together, again according to the Chaku-Chaku principle. The cycle time here is around 50 s.

Table 2 displays the essential data characterising the three samples. While A1 features three points of data collection, the Chaku-Chaku assembling units (A2 and A3) report only two points of data collection since this work-system was only introduced between 2008 and 2009. In the following presentation of results, the focus will lie primarily on assembly A1, as this unit will be compared to plant B. A2 and A3 will only be considered in brief examples here [for a complete record of findings concerning the comparison of A1, A2 and A3 please refer to Enríquez Diaz(2012)].

The participants in plant B are active at the first 80 workstations in final vehicle assembly where they fit customer-specific wiring harnesses and install some

Table 2 Average cycle times [s] during the period of data collection in each sample group

	1.DC	2.DC	3.DC
Plant A1	85	74	74
Plant A2	25*	25	
Plant A3	50	49	
Plant B	72	69	64

* Indicates a theoretical numerical value

additionally components for the vehicle interior. The work setting is an assembly line, more precisely a walk-on conveyor belt on which the employees ride alongside the vehicle during assembling, with height-adjustable assembling platforms. The cycle time varied between 72 and 64 s over the data collection period. It should be noted here that cycle times can be marginally adapted to meet specified quantities.

The employees have been engaged in the four different work systems for an average of 4–18 years (see Table 3). The relatively long periods of employment within one work system derogates the flexible placement in other work systems but ensures a rather high degree of routine when accomplishing given tasks.

A substantial amount of organisational effort was required to follow up on the participating employees during the longitudinal survey period. In this process, it must be guaranteed that participants are distinctly yet anonymously assigned to their individual sets of previously collected data. The chosen procedure was approved by the relevant departments and stakeholders at the two respective companies including the commissioner for data protection, the workers council, the occupational health and safety division and the human resources department.

The employees, who participated in the survey voluntarily,answered the questionnaires during the regular working time. During this time, their tasks were taken over by a so-called swing-man (German: Springer), a stand-by man. The accrued costs (the result of inactive working time) were covered by the companies. The costs incurred during the second data collection in plant B were covered by the project sponsor, the German Research Foundation (DFG), since the financial situation of the company was very tense at the time due to the market downturn in 2008.

As Table 1 shows, the sample size diminishes in both plants over the course of the longitudinal study: In plant A1 a drastic decline of participants can be observed between the data collections, from 185 at 1.DC to 19 at 3.DC, while plant B shows a decline from 242 at 1.DC to 80 participants at 3.DC. The dwindling of participants can be attributed to in-plant fluctuation and the changing business situation of the individual manufacturing components.

To assess the economic effect and the impact of the respective work organisation on the employees in terms of an inter-company comparison, the surveys of the second and third data collection were extended to include a larger area of focus. This means that the cross-sectional samples are considerably larger in number (compare Table 1), enabling a comparison between the two plants (A1 and B).

Table 3 Average period of employment (in years) in the analysed work system at the time of data collection

	Cross section			Longitudinal section
Data collection	1.DC	2.DC	3.DC	1.DC
Plant A1	10.8	10.6	8.2	9.8
Plant B	11.9	14.4	15.9	11.9
Plant A2	4.4	4.1	–	4.8
Plant A3	14.8	8.3	–	18.4

Methods and Procedures

Standardised observational methods and interview methods were used to allow for comparative recording of employee strain and stress throughout the study period of 6 years. The two observational methods used (NIOSH and OWAS) require video recording for data analysis. The remaining data-collecting techniques are survey-based. Conversations with the management, work councils and employees are also considered. Using group discussions, interim results from surveys and workplace, observations were reviewed with employees in plant A. An appropriate presentation of collected data could not be arranged with plant B.

Assessment Criteria of Group Work

Through expert interviews (direct supervisors, group spokesman and manager for group activities) and the use of a checklist concerning group work (Freiboth 1998; Frieling and Sonntag 1999), the working structures are categorised according to 45 items into the following six dimensions: organisational framework, group activities, participation, group discussions/round table, qualification, and continuous improvement process (CIP).

NIOSH Method

The NIOSH method assesses load-handling by utilising various assessment criteria (such as energetic, bio-mechanical, psycho-physical and epidemiological criteria). Like the OCRA method, this technique takes criteria into account that are relevant to the specific task (e.g. load distance and lift height) (Bongwald et al. 1995). The current study uses the extended version of the NIOSH method (see Waters et al. 1993).

OWAS Method

Developed in the mid 1970s in a Finnish steel mill, the OWAS method (Ovako Working Posture Analysing System) is an approved technique in the occupational sciences for classifying and assessing/evaluating body postures, particularly in conjunction with load-handling (Ellegast 2005).

Questionnaire: Healthy Aging Through the Use of Work Design

To depict the subjective state of health of the employees, a questionnaire was compiled on the basis of existing tests. This comprehensive tool consists of more than one hundred items. On average, it takes an employee 50–60 min to fill out the entire questionnaire. A member of staff from the Institute of Industrial Psychology was present at all times during data collection to answer any questions that arose.

The following list displays the selected questionnaires that were chosen for the assessment (for further details please refer to the references):

- Questions regarding complaints of the musculoskeletal system: Nordic Questionnaire–NQ by Kuorinka et al. (1987).
- Short version of the Work Ability Index (WAI) by Nübling et al. (2004).

- Job satisfaction by Neuberger and Allerbeck (1978).
- Salutogenetic Subjective Work Analysis (Salutogenetische Subjektive Arbeitsanalyse)—SALSA by Rimann and Udris (1997).
- German short version of the Big Five Inventory—BFI-K by Rammstedt and John (2005).

Results

Based on comprehensive description of the work organisation, within the analyzed work systems we presented data regarding strain and attitude towards work.

The significance level applied to all analyses is $\alpha = 0.05$. A repeated measures analysis of variance (ANOVA) is used for the longitudinal analysis. Comparisons of groups are done using an ANOVA and post-hoc tests.

Work Organisation

Teamwork

Teamwork plays a major role in work organisation. The essential circumstances for this are formally upheld in both plants through collective agreement (plant A since 2007, plant B since 1995). A standardised checklist (Freiboth 1998; Frieling and Sonntag 1999) is used to ensure an objective evaluation of teamwork in the plants (Fig. 2).

The significant differences in the categories “organisational framework” and “expanded team activities” are particularly distinct between plant A2 and the other plants, where plant A2 achieves the higher percentile score. Of note are the low scores in plant B for the dimensions “participation”, “qualification”, “team discussions” and “CIP activities”. These poor grades in plant B are ascribed to infrequent discussions within the group. Whilst in plant A group discussions take place once a week, in plant B this occurs only every 2 months, or when the conveyor belt stands still for longer periods of time, for example due to a technical malfunction (cf. Sytch et al. 2011). The number of participants attending such group discussions in plant B usually exceeds 50 persons (two groups). A comparison of the span of control at team level in plant A and B demonstrates that teamwork is barely practical in plant B due to the working structure adopted there.

Span of Control

The size of the span of control determines how present and approachable the direct supervisor is for his employees. Personal and close contact with the employees within an integral production system is necessary for ongoing troubleshooting, process optimisation and competency development. Table 4 shows a current distribution of leaders, starting from the team spokesperson to the foreman level.

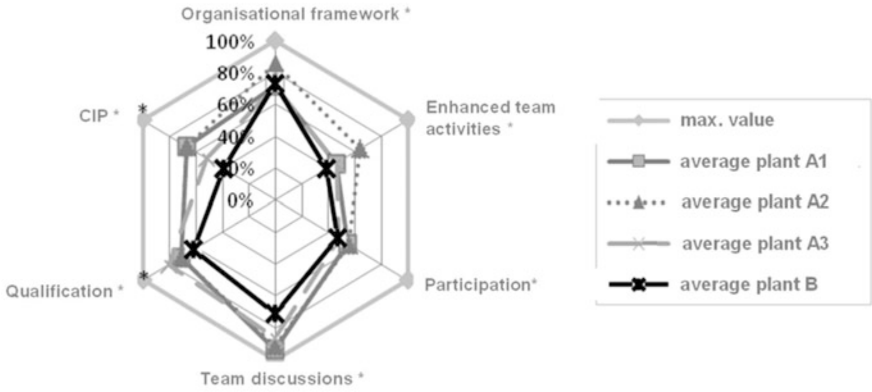


Fig. 2 Graphical comparison of the categories in the examined assembly units (mean normalized values) *The difference of the mean scores is significant at level 0.05

Table 4 Span of control in the four sample groups

	Plant A1	Plant A2	Plant A3	Plant B
Foremen total	3	1	3	6
Employees per foreman	About 30	About 18	About 25	About 50
Team spokesperson total	9	3	9	6
Employee per team spokesperson	About 10	About 6	About 7–8	About 25

It is striking that in plant B approximately 50 employees are assigned to one foreman per shift and 25 employees to one team spokesperson. During the study period (2006–2011) the foremen's areas were downsized from five to three divisions. Depending on the shift, two foremen are available for one area. The management in plant B very consciously weakens the role of the participatory team spokesperson in their newly implemented work structure (2011/12). Instead, the team spokesperson is replaced by a "deputy-foreman", who is responsible for approximately ten employees.

Shift Systems and Cycle Times

During the period of the three data collections, the employees in plant B worked in a two-shift system (early and late shift alternating on a weekly basis). The early shift begins at 5 a.m. The late shift begins at 1:30 p.m. and ends at 10:00 p.m.

The employees engaged in production in plant A mostly work in a backward-rotating shift system of early shifts, late shifts and night shifts. The early shift starts at 6:30 a.m., the late shift starts at 2:30 p.m., and the night shift starts at 10:30 p.m. However, this is only one of many different working time models found in plant A.

From an industrial psychology perspective, the shift system in plant B is particularly problematic, as the employees need to get up between 3 and 4 a.m. to get to work on time (see also Chap. Development and Evaluation of Working-Time

Models for the Ageing Workforce. Lessons Learned from the KRONOS Research Project, Knauth et al.).

Among the assessed assembling tasks, cycle times play a crucial role as they determine workflow, high repetition rates and standardised operations. When examining the four different assembling systems, one sees that in three of the four assembling units a reduction of the cycle time occurred during the study period, leading to a substantial productivity increase (see Table 2). One exception is the hand brake lever assembly. In this working system no exact cycle time could be determined, since the assembling system was in its start-up phase at the point of the first data collection and the average cycle times were still subject to great variation. Upon the implementation of the system, the cycle time played a subordinate role. Due to frequently occurring faults in the new system, troubleshooting, maintenance and repairs had to be optimised first. Therefore, only a theoretical value of 25 s, when everything runs smoothly, can be given as cycle time (Table 5).

The cycle time reduction brings about optimised performance and higher productivity. This is intended to avoid non-value adding tasks, such as walking, searching for material or preparation of components. This leads to a one-sided workload and the avoidance of hidden breaks (Kotzab et al. 2011).

Ergonomic Evaluation of the Work Systems

The following section focuses on body postures and handling of loads, as these are associated with the physical complaints we examined. For detailed data concerning the ergonomic analysis, see Enríquez Díaz (2012).

Loads (weights) have a greater impact on physical strain for equipment assembly than for wiring harness assembly. Consequently, the results of the gearbox assembly (A1) are displayed below. Overstepping of the critical value of 1.0 is interpreted in terms of a strain risk according to the NIOSH method. During the course of the study a slight risk decrease was observed, which can be attributed to the increased use of lifting aids and the introduction of ergonomic improvement measures (e.g. the reduction of awkward body postures, as well as a modification of the start and end position of the manipulated load weight) (Fig. 3).

The contributing effect of the lifting aids is revealed in the categorisation of the three workstations in plant B (Fig. 4) at which the work is performed with and without lifting aids. The analysis shows that the utilisation of ergonomically designed lifting aids is a prerequisite for their acceptance (among the employees) and that their implementation leads to a considerable lessening of physical strain risks.

The longitudinal study conducted in plant B using the OWAS method (Fig. 5) reveals that the strains related to working posture show a downward trend (for example, in the back, leg and head region) while a rise in strain can only be observed for the arm region. The reasons for this increase are the larger number of

Table 5 Shift times and break times of plant B and plant A1, A2 and A3

Shift	Begin	Break 1	Break 2	Break 3	End
Plant B					
Early	5:00 a.m.	7:55 a.m. (15 min)	10:45 a.m. (30 min)		1:30 p.m.
Late	1:30 p.m.	5:30 p.m. (30 min)	8:15 p.m. (15 min)		10:00 p.m.
Plant A1, A2 and A3					
Early	6:30 a.m.	8:30 a.m. (16 min)	10:30 a.m. (30 min)	12:30 p.m. (16 min)	2:30 p.m.
Late	2:30 p.m.	4:30 p.m. (16 min)	6:30 p.m. (30 min)	8:30 p.m. (16 min)	10:30 p.m.
Night	10:30 p.m.	12:30 a.m. (16 min)	2:30 a.m. (30 min)	4:30 a.m. (16 min)	6:30 a.m.

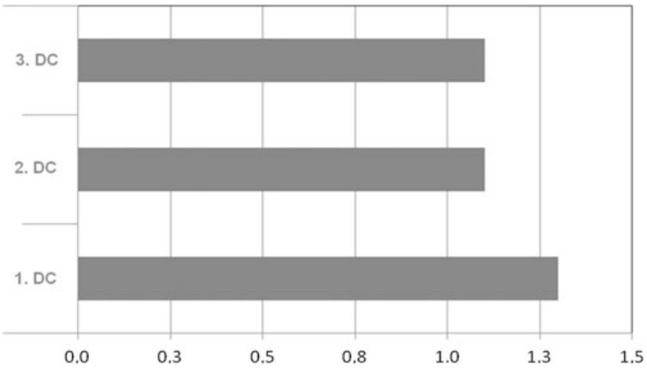


Fig. 3 Presentation of the combined lifting index (CLI) according to the NIOSH method for the analysed work places in plant A1 (N = 5 work stations)

assembling tasks that need to be done in the vehicle interior (utilisation of riveting machines) and the accessibility of the mounting site in the rear lid assembly.

The OWAS-rated working postures in workstation (8) vehicle interior assembly top, (7) vehicle interior assembly bottom and (6) exterior assembly (boot, engine compartment) are particularly problematic, as shown in Fig. 6. Due to the increasing complexity of the wiring harness and the interior design, new tasks emerge in the vehicle interior that must be performed on top of cycle time reduction and without compensatory movements.

As the evaluation of the survey data (see section Physical Complaints) demonstrates, the implemented ergonomic aids cannot significantly contribute to the reduction of physical complaints caused by awkward working postures; on the contrary, the physical complaints increase. This is primarily caused by cycle time reduction and the loss of compensatory movements and hidden micro-breaks. One of the production planners' targets is to raise the employees' degree of utilization

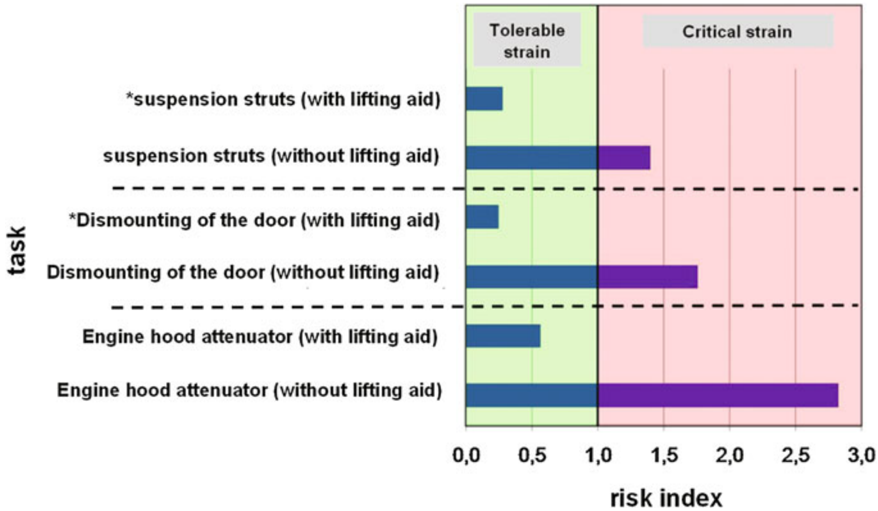


Fig. 4 NIOSH rating of assembly tasks with and without lifting aids at three selected work stations (plant B). *Note* The use of lifting aids reduces the risk index (NIOSH 91) by roughly 80 % and moves it from a red risk classification (critical) to a green risk classification

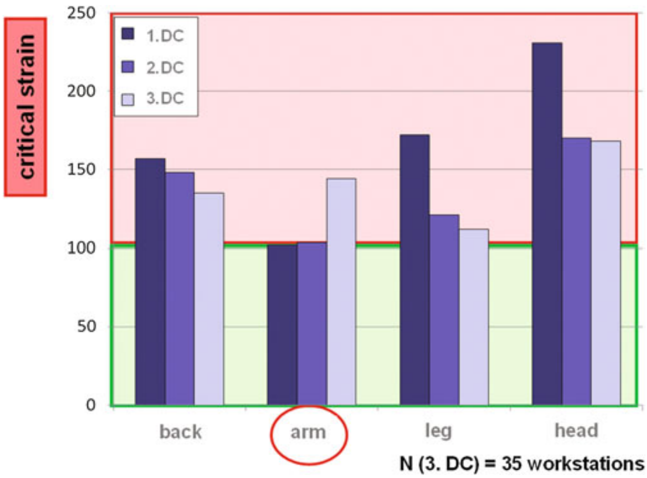
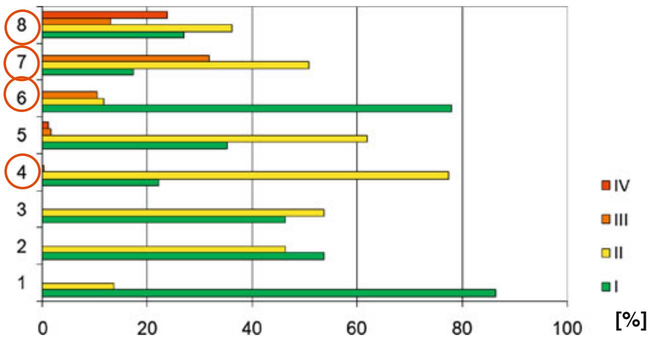


Fig. 5 OWAS rating of selected work places in plant B. *Note* Range 100–400 is (physically) stressful

to 95 % or higher by avoiding wastage. This goal increases physical strain, particularly among older employees.

In the Chaku–Chaku work systems (plant A2 and A3), the working postures and the required lifting and carrying of loads are inconspicuous (see also Enríquez



Assembling points on the vehicle	
1. Assembling on the outside, while the employee is outside the vehicle	5. Assembling on the interior (lower section), while the employee is outside the vehicle
2. Assembling under the bonnet, while the employee is outside the vehicle	6. Assembling on the interior (lower section), while the employee is outside the vehicle
3. Assembling under the tailgate, while the employee is outside the vehicle	7. Assembling on the interior (on the undertray and the lower section), while the employee is inside the vehicle
4. Assembling on the interior (on the undertray), while the employee is outside the vehicle	8. Assembling on the interior (upper section), while the employee is inside the vehicle

Fig. 6 OWAS categorisation of measures for assembling positions on the vehicle in plant B

Diaz 2012). The short cycle times (25 and 50 s respectively) and the avoidance of compensatory movements (wastage) cause the distinct physical complaints found in these systems (see below).

Physical Complaints

Below is a list of six body regions, recorded using the Nordic Questionnaire, and related physical complaints, both cross-sectional and longitudinal. Where available, the comparative data of the representative BiBB/BAuA study (Bundesanstalt 2005/2006) conducted among 20,000 employees in 2005/2006 is provided. The percentage of persons with the respective physical complaints is also given.

Neck

The scores relating to the neck region deteriorate significantly in plant B across the longitudinal data evaluation. This can be attributed to a large extent to the twisting of the head during the assembly in the interior. During the second data collection, 100 % of the employees of the Chaku–Chaku system in plant A2 complain about neck ache. Plant A1 on the other hand, shows a significant change that manifests itself only in the cross-section and that can be explained by the varying structure of the group (Table 6).

Shoulder

The extent of complaints concerning the shoulders is largely comparable to that of the neck. It shows a significant increase of complaints in plant B. More still, all employees engaged in the Chaku–Chaku assembly system in plant A2 report complaints in this body region. A likely explanation for this condition can be found in the short-cycled, monotonous assembling movement and the assembling platforms that are not individually adjustable in height. Plant A3 shows a relatively constant record of complaints over time (Table 7).

Wrist

The significant increase of complaints in the wrist in plant B (Table 8) makes it quite clear that the ergonomic conditions in this division have not improved. The utilisation of heavy riveting tools and their handling in narrow spaces (e.g. vehicle interior) is very strenuous in the hand and arm region; the same applies for clipping tasks. Here, thumb pressure is needed, which requires an expenditure of effort up to 130 N. A significant deterioration is observed in plant A2 and A3. These severe findings are presumably a result of the high repetition rates of the individual operations and the lessening of micro breaks.

Table 6 Longitudinal (L) and cross-sectional (CS) view of physical complaints (%)—neck pain

		1.DC	2.DC	3.DC
Plant A1	L	44.4 (N = 17)	55.6 (N = 17)	41.2 (N = 17)
	CS	38.3 (N = 175)	55.3* (N = 179)	53.2* (N = 62)
Plant B	L	53.7 (N = 67)	50.8 (N = 67)	68.7*/** (N = 67)
	CS	50.9 (N = 216)	49.3 (N = 144)	66.0 (N = 100)
Plant A2	L	88.9 (N = 9)	100.0 (N = 9)	–
	CS	62.5 (N = 16)	84.6 (N = 29)	–
Plant A3	L	45.5 (N = 11)	45.6 (N = 11)	–
	CS	61.9 (N = 21)	36.7 (N = 30)	–

Note
*Means a significant diff. to the first DC
**Means a significant diff. to the second DC; (BiBB/BAuA comparative value for persons below the age of 45, 42 %, and above the age of 45, 45 %)

Table 7 Longitudinal (L) and cross-sectional (CS) view of physical complaints (%)—Shoulder

		1.DC	2.DC	3.DC
Plant A1	L	35.3 (N = 17)	35.3 (N = 17)	41.2 (N = 17)
	CS	25.3 (N = 170)	44.6 (N = 177)	47.5 (N = 59)
Plant B	L	40.3 (N = 62)	54.8* (N = 62)	58.1* (N = 62)
	CS	44.4 (N = 216)	46.9 (N = 144)	55.7*/** (N = 100)
Plant A2	L	77.8 (N = 9)	100 (N = 9)	–
	CS	60.0 (N = 16)	89.3 (N = 26)	–
Plant A3	L	50.0 (N = 8)	50.0 (N = 8)	–
	CS	60.0 (N = 20)	50.0 (N = 28)	–

Note
*Means a significant diff. to the first DC
**Means a significant diff. to the second DC; (BiBB/BAuA comparative value for persons below the age of 45, 42 %, and above the age of 45, 45 %)

Table 8 Longitudinal (L) and cross-sectional (CS) view of physical complaints (%)—Wrist

		1.DC	2.DC	3.DC
Plant A1	L	23.5 (N = 17)	23.5 (N = 17)	17.7 (N = 17)
	CS	18.6 (N = 167)	29.5* (N = 173)	27.4 (N = 62)
Plant B	L	37.1 (N = 62)	48.4 (N = 62)	46.8 (N = 62)
	CS	38.7 (N = 204)	44.2 (N = 138)	52.4* (N = 98)
Plant A2	L	25.0 (N = 8)	50.0 (N = 8)	–
	CS	40.0 (N = 15)	55.6 (N = 27)	–
Plant A3	L	55.6 (N = 9)	55.6 (N = 9)	–
	CS	60.0 (N = 20)	41.4 (N = 29)	–

Note
*Means a significant diff. to the first DC; (BiBB/BAuA comparative value for persons below the age of 45, 19 %, and above the age of 45 years, 22 %)

The great variation between the CS group and L group in plant A1 is striking: while from a longitudinal perspective no significant change can be detected, the cross-sectional analysis reveals a distinct negative development (different group structures!).

Upper Back

The upper back shows a slight to strong negative development in all assembly units when comparing to the first data collection. It should be noted here that in plant A1 the frequency of complaints declined during the second data collection. This is probably due to ergonomic improvements that were implemented in plant A1 between the first and second data collection (see section Ergonomic Evaluation of the Work Systems). However, plant B shows a distinct trend towards increased discomfort in the upper back (Table 9).

Lower Back

The lower back analysis gives the same picture as the upper back analysis, but with an even higher incidence of complaints. The findings in plant A1 are characterised by strong fluctuations. The improvements seen here between 2.DC and 3.DC can be ascribed to the ergonomic action taken (introduction of lifting aids). The extent of complaints registered in plant B resembles that of plant A2 (Table 10).

Table 9 Longitudinal (L) and cross-sectional (CS) view of physical complaints (%)—upper back

		1.DC	2.DC	3.DC
Plant A1	L	29.41 (N = 17)	52.94* (N = 17)	35.29 (N = 17)
	CS	26.53 (N = 167)	41.04 (N = 173)	32.79 (N = 161)
Plant B	L	38.98 (N = 59)	42.37 (N = 59)	47.46 (N = 59)
	CS	36.82 (N = 201)	35.77 (N = 137)	48.98*/** (N = 98)
Plant A2	L	44.44 (N = 9)	55.56 (N = 9)	–
	CS	43.75 (N = 15)	50.00 (N = 27)	–
Plant A3	L	44.44 (N = 9)	44.44 (N = 9)	–
	CS	55.00 (N = 20)	27.59 (N = 29)	–

Note
*Means a significant diff. to the first DC
**Means a significant diff. to the second DC; (BiBB/BAuA comparative value for persons below the age of 45, 40 %, and above the age of 45, 42 %)

Table 10 Longitudinal (L) and cross-sectional (CS) view of physical complaints (%)—lower back

		1.DC	2.DC	3.DC
Plant A1	L	58.8 (N = 17)	82.4 (N = 17)	47.1** (N = 17)
	CS	52.3 (N = 174)	61.5 (N = 179)	61.0 (N = 59)
Plant B	L	67.1 (N = 70)	65.7 (N = 70)	77.1 (N = 70)
	CS	71.1 (N = 225)	68.3 (N = 145)	79.8** (N = 104)
Plant A2	L	71.4 (N = 7)	71.4 (N = 7)	–
	CS	76.5 (N = 17)	75.0 (N = 24)	–
Plant A3	L	80.0 (N = 10)	80.0 (N = 10)	–
	CS	71.4 (N = 21)	50.0 (N = 28)	–

Note
*Means a significant diff. to the first DC
** Means a significant diff. to the second DC; (BiBB/BAuA comparative value for persons below the age of 45, 40 %, and above the age of 45, 42 %)

Knee

Strain on the knees remains constant and at a relatively high level in plants A3 and B (compared with the BiBB/BAuA sample). By constrast, plant A1 shows a slight increase of complaints. A distinct improvement in plant A2 can be observed in the longitudinal analysis, yet this is not reflected in the cross-sectional data (group structure). The improvement in plant A2 is largely due to the use of shoes with high shock absorbing and cushioning properties and compensatory movements as part of the job rotation (material supply) (Table 11).

Summary of Physical Complaints

Despite attempts to move towards more ergonomic work design (implementation of lifting aids, steps for height adjustment, changes in the line balances, shoes with high shock absorbing properties, etc.), the changes made to the working conditions did not lead to a significant reduction of physical complaints. The reasons for this are other changes aimed at optimised performance and cycle time reduction; the omission of hidden micro-breaks and compensatory movements (going, fetching parts); the standardisation of sequence of movements at very high repetitive levels; and the low proportion of time allocated to secondary tasks (material supply, maintenance and repairs, quality assurance, optimisation of workflow, etc.). This is particularly true in plant B, where (the model of) a value-oriented production system has been adopted and the concept of participative teamwork has been dismissed.

Table 11 Longitudinal (L) and cross-sectional (CS) view of physical complaints (%)—Knee

		1.DC	2.DC	3.DC
Plant A1	L	26.7 (N = 15)	33.3 (N = 15)	46.7 (N = 15)
	CS	28.4 (N = 169)	36.9 (N = 176)	40.7 (N = 59)
Plant B	L	44.1 (N = 59)	49.2 (N = 59)	50.9 (N = 59)
	CS	48.3 (N = 211)	42.0 (N = 138)	50.0 (N = 92)
Plant A2	L	62.5 (N = 8)	25.0* (N = 8)	–
	CS	50.0 (N = 16)	48.2 (N = 27)	–
Plant A3	L	44.4 (N = 9)	44.4 (N = 9)	–
	CS	27.3 (N = 22)	34.5 (N = 28)	–

Note
*Means a significant diff. to the first DC; BiBB/BAuA comparative value for persons below the age of 45, 18 %, and above the age of 45, 21 %

As the listed physical complaints generally increase with age (cf. BiBB/BAuB data), the new work concepts (featuring integrated production systems) are likely to worsen physical complaints and decrease the likelihood of employees performing this work until reaching the statutory retirement age.

Work Ability Index

The Work Ability Index (WAI) (Ilmarinen and Tempel 2002) is subject to an age-related decline that can be moderated through better working conditions. Table 12 reveals how differently WAI scores developed in the various plants (over the course of the study). A significant downward trend can be observed in the longitudinal analysis of plant B, and this trend is also visible in the cross-sectional data. Plants A1 and A2 display a similar trend during the first two data collections. However, in the third data collection, plant A1's WAI scores show a slight improvement. In constrast, plant A3 is the only assembly system that features a significant improvement between both data collections. These findings support the hypothesis of Ilmarinen and Tempel (2002), who argue that work design can keep a WAI score constant and even improve it in some cases. Plant A3 is such an exception. This plant launched a number of alterations in the work process, such as replacing physically strenuous welding tasks with welding systems, replacing very loud engraving machines with low-noise embossing machines, stepping up teamwork using continuous improvement activities and adopting an employee-oriented leadership style. Overall it can be said that the WAI scores can be graded as "good". This corresponds with the moderate rate of absenteeism. These rates fluctuate over the course of the study, in plant A1 between 3 and 5 %, in plant B

Table 12 Longitudinal changes in the WAI

Plant	1.DC	2.DC	3.DC	N
A1	39.1	38.3	38.9	18
B	38.8	37.3*	36.7*	79
A2	36.1	35.7	–	10
A3	29.5	37.8*	–	11

*Means a significant diff. to the first DC; (WAI scores: 49–44 very good, 43–37 good, 36–28 moderate, and below 27 poor)

between 4.2 and 5 %, in plant A2 between 4.1 and 9.3 %, and in plant A3 between 4.8 and 5.9 % (Table 13).

When looking at the cross-sectional WAI scores (plant B) in the three age groups, a significant difference can be observed (see Table 14).

A different picture emerges from a longitudinal perspective (Table 15), with a steady deterioration in the youngest and the middle age group and constancy or an improvement in the oldest age group. Here, in line with the healthy-worker effect, it can be assumed that only persons in relatively good health are employed at the assembly lines.

Job Satisfaction

In accordance with Ilmarinen and Tempel (2002) we assume a positive correlation between work ability and job satisfaction. Consequently, it is no surprise that scores for job satisfaction are subject to corresponding, comparable changes. The job satisfaction results are positive (the scale goes from 1 meaning low to 7 meaning high)—except for plant B, where a significant deterioration in job satisfaction can be observed between 1.DC and 3.DC. This deterioration is both longitudinal and cross-sectional: 4.7(L)/4.7 (CS) (1.DC) fell to 4.5 (L)/4.6 (CS) (2.DC) and then to 4.2 (L)/4.1(CS) (3.DC). Within the group of employees aged 45 years and above, job satisfaction remained stable (4.7), whilst the greatest decline occurred in the group of 36–45 year-olds (from 4.8 down to 4.1, N = 29).

Subjective Work Analysis (*SALSA*)

Only selected findings from the subjective work analysis that were considered particularly relevant are presented here. Employee-oriented behaviour of supervisors is viewed more critically in plant B than in plant A1. Employee-oriented

Table 13 Cross-sectional changes in the WAI

Plant	1.DC	2.DC	3.DC	N1/N2/N3
A1	38.8	37.7	39.3	185/186/65
B	37.6	36.9	36.2	242/153/109
A2	36.5	35.9	–	18/29
A3	30.6	38.5*	–	22/35

*Means a significant diff. to the first DC; (WAI scores: 49–44 very good, 43–37 good, 36–28 moderate, and below 27 poor)

Table 14 Cross-sectional WAI scores (plant B); significant diff. between: 1 and 2; 1 and 3; 2 and 3

	Below 35 (N = 93)	36–44 (N = 77)	45+ (N = 66)
WAI	39.92	37.42*	34.83*/**

*Means a significant diff. to the first DC
**Means a significant diff. to the second DC

Table 15 Longitudinal WAI scores according to age groups (plant B)

	Below 35 (N = 37)	36–44 (N = 28)	45+ (N = 14)
1.DC	41.00	37.61	35.36
2.DC	39.76	35.11	35.07
3.DC	38.27	34.79	36.57

leadership behaviour in plant A1 showed a positive development over the course of the study. In the longitudinal analysis, ratings deteriorate when there is a direct supervisor change during the survey period. No such phenomenon can be observed in the cross-sectional data. This means that those persons who experience a change over time are more critical than those who merely rate their current situation. However, this assumption requires further investigation.

An interesting aspect of the findings from the subjective work analysis is the rating of task identity (see Table 16). As the assembled products greatly differ in terms of complexity, it is understandable that the appraisal of task identity varies. Completing a component (handbrake lever, plant A2) and assembling the gearbox (plant A1) is certainly experienced as more holistic than assembling a wiring harness (plant B) or assembling a component for the exhaust system (plant A3).

A significant decrease is noted in plant B. Presumably this is due to the limitation of different cycles (approximately 7–8) per employee, depending on their wage group.

Task diversity (see Table 17) rises in plants A1 and A3, while it decreases in plants A2 and B. In other words, standardisation, reduced cycle times and avoidance of waste (especially in plant B) happen at the expense of task variety. In plant A2, the decrease can be explained due to a reduction in technical faults. Technical measures and retrofitting caused malfunctions in individual systems to decline and output to rise, while the input required for maintenance, repairs and troubleshooting fell. However, now that everything is running smoothly and employees can focus on their core tasks, the effect of the short cycle time of 25 s is perceived to be far more intense.

Within the framework of her strain-biography study, Weichel (2012) used the 1.DC–plant B sample to show that task diversity at the workplace is the best predictor of adaptive performance. This means that high task diversity enables employees to handle new challenges more efficiently.

Limited task diversity also minimises chances of participation in decision-making and decision-shaping processes (opportunities for participation). The generally weak

Table 16 Task identity

		1.DC	2.DC	3.DC
Plant A1	L	3.4 (N = 18)	3.2 (N = 18)	3.2 (N = 18)
	CS	3.2 (N = 182)	3.1 (N = 199)	3.6*/** 9N = 65)
Plant B	L	2.7 (N = 77)	2.6 (N = 77)	2.4*/** (N = 77)
	CS	2.6 (N = 235)	2.6 (N = 153)	2.4 (N = 108)
Plant A2	L	3.6 (N = 10)	3.8 (N = 10)	–
	CS	3.8 (N = 18)	3.4 (N = 29)	–
Plant A3	L	2.9 (N = 11)	2.8 (N = 11)	–
	CS	3.0 (N = 23)	3.0 (N = 34)	–

Note
Scale 1 (not true) to 5 (very true)
*Means a significant diff. to the first DC
**Means a significant diff.to the second DC

Table 17 Task diversity

		1.DC	2.DC	3.DC
Plant A1	L	2.9 (N = 19)	3.4* (N = 19)	3.1 (N = 19)
	CS	2.8 (N = 184)	2.7 (N = 203)	3.1 (N = 65)
Plant B	L	2.7 (N = 81)	2.6 (N = 81)	2.5 (N = 81)
	CS	2.7 (N = 241)	2.6 (N = 155)	2.5 (N = 109)
Plant A2	L	2.6 (N = 10)	2.3 (N = 10)	–
	CS	2.3 (N = 18)	2.1 (N = 29)	–
Plant A3	L	2.1 (N = 11)	2.4 (N = 11)	–
	CS	2.4 (N = 23)	2.5 (N = 35)	–

Note
Scale 1 (not true) to 5 (very true)
*Means a significant diff. to the first DC

Table 18 Opportunities for participation

		1.DC	2.DC	3.DC
Plant A1	L	2.8 (N = 18)	2.8 (N = 18)	2.6 (N = 18)
	CS	2.7 (N = 183)	2.7 (N = 200)	2.7 (N = 65)
Plant B	L	2.5 (N = 80)	2.2 (N = 80)	2.3 (N = 80)
	CS	2.6 (N = 239)	2.3* (N = 154)	2.3* (N = 109)
Plant A2	L	2.5 (N = 10)	2.4 (N = 10)	–
	CS	2.4 (N = 18)	2.4 (N = 19)	–
Plant A3	L	2.6 (N = 11)	2.8 (N = 11)	–
	CS	2.7 (N = 23)	2.9 (N = 34)	–

Note
Scale 1 (not true) to 5 (very true)
*Means a significant diff. to the first DC

values (see Table 18) are weakest in plant B. Here it becomes obvious that the applied teamwork concept allows very little room for participation. It is striking that while the objective differences between plants A and B regarding opportunities for participation (see Fig. 2, teamwork) are large, the subjective employee ratings do not reflect these differences. This means that although chances of participation in plant A are objectively much higher due to certain organisational structures, they are not subjectively rated as such. For example, employees in plant A2 worked out design proposals regarding the colour and interior organisation that were later implemented. No such phenomenon can be found in plant B.

The least scope (between 1.2 and 1.7) is conceded to personal design of the workplace. In this regard, the plants barely differ from each other. The lowest scores (1.2–1.5) are recorded in plant B.

These findings are particularly problematic in terms of the aging workforce, as the prevailing planning philosophy does not officially permit individual leeway (e.g. individual work piece buffer, special storage space for parts, seating, etc.). Personal latitude clashes with endeavours to maintain standardised processes.

Personality Inventory

Data from the Big Five Inventory (BFI) and the Irritation Scale reveal nothing unusual. As expected, the BFI values change little over the survey period (the correlations vary between 0.49 and 0.86). The same can be said for cognitive and emotional irritation, where scores for overall irritation range from 2.8 to 3.8. Substantial differences between the individual plants were not detected.

Concerning the survey data, it should be mentioned that the participants made an effort to complete the questionnaires very conscientiously. One indicator for this is the accuracy of values given for body height. Correlations for body height are between 0.98 and 0.99 for the first, second and third data collection.

Work Design in Interaction with the Research Team

Cooperation between the researchers, the management, the workers' council and the employees differed greatly in the two companies. In plant B, neither the necessary data feedback nor discussions concerning direct interventions at the assembly line could be realised. All that was adopted there was the idea of implementing a strain-oriented, company-wide IT-based system (see Stanic 2010) for facilitating of job-rotation. Technical implementation of the IT has largely been fine-tuned, but the practical launch is not yet complete (as of 2011). Suggestions regarding the short cycle times, potential pre-assembling of modules and alterations to the product (e.g. separate tailgate assembly) were registered but not discussed in a serious manner.

In contrast, data feedback in plant A (A1, A2 and A3) was utilised to discuss feasible suggestions for improvement. Specific actions were derived from the discussions and partially implemented:

In A1: implementation of lifting aids, implementation of lifting devices to facilitate the retrieval of parts from a pallet box, avoidance of direct glare at the assembling stations, improved material supply.

In A2: colouring in the entire assembling and recreational area, improvement of material supply by means of suitable stepladders, job rotation between material supply and assembly, installation of an assembling station for physically disabled persons, optimisation of maintenance and repairs, application of therapeutic exercises to relieve complaints in the neck, shoulder, hand and arm region, etc.

In A3: noise-level reduction through implementation of new low-noise stamping press [below 40 db (A)] instead of the very loud needle press [up to 95 db (A)], implementation of welding systems to avoid awkward body postures, ergonomic optimisation of material supply, testing area and welding appliances, plus floor mats and lighting at certain workstations, etc.

The different approach towards the realisation of actions in the two companies is obvious. A key reason for the unwillingness to change at plant B is that modifications on the final assembly line bear a high economic risk due to their linkage with other assembling areas. In contrast, risks entailed by changes in the aggregate assembly can be controlled more easily.

Conclusion

The aim of the project "Age-differentiated work design in the automotive assembly" was to determine the age-related impact that typical assembling tasks have on employees. Various tasks in final vehicle assembly and equipment assembly were examined at two automotive companies. These tasks are characteristic of the automotive and supplying industry.

Within the project period, the automotive industry faced substantial economic fluctuations, the consequences of which are visible in the collected data.

In the first phase of the project, the two companies' interest in "demographic questions" was comparable. Company A's response to the subject matter was a comprehensive collective agreement and company B initialised a project to deal with the aging workforce. While company A's interest in the project grew over the years, backed by the management and the worker's council, company B's interest in the matter steadily dwindled. This adverse development affected data collection and the handling and treatment of the results.

During the project it became clear that differentiated work systems (plant A2 and A3) are better suited for implementing and evaluating measures of work design customised for an ageing workforce than the rather extensive work systems found in the final vehicle assembly area (plant B). Strong support from the worker's council in plant A was a prerequisite for the success of the project. The worker's council in plant B supported data collection but they did not follow up on the findings.

The comparable methods and instruments of value-oriented production systems found in both companies lead to an increase in productivity in conjunction with similar effects on the employees.

Cycle times are reduced, hidden breaks are omitted, and non-value adding activities (e.g. material supply) are eliminated, increasing efficiency. These rationalisations culminate in the examined Chaku–Chaku work systems, which are characterised by very short cycle times. The ergonomically motivated measures of work design that have been implemented to "improve added value" did not lead to any relief for employees, because shortening the cycle time resulted in a concomitant intensification of work performance. This was the case in plant B and plant A2 in particular.

In the four analysed work systems, physical strain rose during the study period as a consequence of one-sided strain. These strains worsen with age. A similar relationship exists between age and work ability, except that work ability decreases with age. Task diversity and the extent to which work tasks are holistic have significantly decreased in the perception of the employees. The same applies for opportunities for participation and personal latitude.

Overall job satisfaction did not change. Satisfaction with the company is high in both plants, which means that the perceived deterioration of working conditions (especially in plant B) did not lead to dissatisfaction with the company as a whole.

Job rotation measures alone are not sufficient when customising work systems to meet the demands of an aging workforce. The recommendations listed under Lessons Learned (see section Lessons Learned) are essential.

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References

Bongwald O, Luttmann A, Laurig W (1995) Leitfaden für die Beurteilung von Hebe- und Tragetätigkeiten: Gesundheitsgefährdung, gesetzliche Regelungen, Messmethoden, Beurteilungskriterien und Beurteilungsverfahren. HVBG, Sankt Augustin

Bundesanstalt für Berufsbildung und Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BiBB/BAuA) (eds) (2005/2006) Arbeit und Berufe im Wandel, Erwerb und Verwertung beruflicher Qualifikationen, Erwerbstätigenbefragung 2005/2006 Dortmund

BMW Annual Report (2011) http://geschaeftsbericht2011.bmwgroup.com. Accessed Aug 2012

Conti R, Angelis J, Cooper C, Farager B, Gill C (2006) The effects of lean production on worker job stress. Int J Oper Prod Manage 26(9):1013–1038

Ellegast RP (2005) Fachgespräch Ergonomie 2004 Zusammenfassung der Vorträge, gehalten während des Fachgespräches Ergonomie am 15/16. November 2004 in Dresden. BGIA, Sankt Augustin (BGIA-Report)

Enríquez Díaz JA (2012) Arbeitswissenschaftliche Evaluation ganzheitlicher Produktionssysteme für die Aggregatemontage in der Automobilindustrie. Dissertation, RWTH Aachen, Fakultät für Maschinenwesen

Freiboth M (1998) Empirischer Vergleich von Arbeitsorganisationsformen in der Automobilindustrie. Dissertation, Universität Kassel

Frieling E, Sonntag KH (1999) Lehrbuch Arbeitspsychologie. Hans Huber, Bern, pp 438–443

Ilmarinen J, Tempel J (2002) Arbeitsfähigkeit 2010 Was können wir tun damit Sie gesund bleiben? VSA-Verlag, Hamburg

Jürgens U (2007) Warum Toyota so lange so stark ist. IG Metall Baden-Württemberg, Stuttgart

Kono H (2004) Fundamental principles and side-effects for effective manufacturing revolution. In: Proceedings of the 5th Asia Pacific industrial engineering and management systems-conference, 23 May 2010

Kotzab D, Enríquez Díaz JA, Sytch A, Frieling E (2011) Changes in employee attitudes towards work activity in a chaku–chaku assembly line—a follow up study in a German automotive manufacturing company. In: ODAM–X (ed) Human factors in organizational design and management: II-81–II-86. IEA Press, Santa Monica

Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, Jørgensen K (1987) Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergonomics 18(3):233–237

Landau K (2011) Arbeitsgestaltung für alternde Belegschaften. ASU-protect Das Magazin für das Arbeitsschutzmanagement, Gentner, Stuttgart, pp 30–33, 1 Nov 2011

Neuberger O, Allerbeck M (1978) Messung und Analyse von Arbeitszufriedenheit. Erfahrungen mit dem Arbeitsbeschreibungsbogen (ABB). Huber, Bern

Neuhaus R (2010) Evaluation und Benchmarking der Umsetzung von Produktionssystemen in Deutschland. Books on den demand, Norderstedt

Nübling M, Hasselhorn HM, Seitsamo J, Ilmarinen J (2004) Comparing the use of the short and the long disease list in the work ability index questionnaire. In: Proceedings of the 2nd international symposium of work ability. ICOH, 18–20 Oct 2004. Verona, p 74

Ohno T (2009) Das Toyota-Produktionssystem: Das Standardwerk zur Lean Production. Campus, UK Frankfurt

Rammstedt B, John OP (2005) Kurzversion des Big Five Inventory (BFI-K): Entwicklung und Validierung eines ökonomischen Inventars zur Erfassung der fünf Faktoren der Persönlichkeit. Diagnostica 51:195–206

Rimann M, Udris I (1997) Fragebogen zur persönlichen Situation im Beruf und Betrieb. Salsa. In: Strohm O, Escher OP (eds) Mensch, Technik, Organisation: Unternehmen arbeitspsychologisch bewerten. Ein Mehr-Ebenen-Ansatz unter besonderer Berücksichtigung von Mensch, Technik und Organisation. vdf Hochschulverlag, Zürich, pp 281–298

Schumann F (1911/2011) Die Arbeiter der Daimler-Motoren-Gesellschaft Stuttgart-Untertürkheim. Herausgegeben von IG Metall Baden-Württemberg. Original: Duncker–und Humblot. Wiederabdruck: INFO IDEE Medienverlag, Ludwigsburg

Stanic S (2010) Fahrzeugendmontage—Herausforderungen für den demografischen WandelSchriftenreihe. Personal–und Organisationsentwicklung. Kassel University Press, Kassel

Sytch A, Kotzab D, Enríquez Díaz JA, Nöring R, Frieling E (2011) Einstufung von industrieller Teamarbeit—Eine Klassifikation ausgewählter Montagesysteme. In: GfA Mensch, Technik (eds) Organisation—Vernetzung: Tagungsband der GfA Frühjahrskonferenz GfA-Press, Dortmund, pp 631–634

Verband der Deutschen Automobilindustrie—VDA (2011) Jahresbericht. Frankfurt a.m

Waters TR, Putz-Anderson V, Garg A, Fine LJ (1993) Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics 36(7):749–776

Weichel J (2012) Ressourcen und Belastungen in der Berufsbiografie. Kassel University Press GmbH, Kassel

Wimmer E, Schneider MC, Blum P (2010) Antrieb für die Zukunft—Wie VW und Toyota um die Pole-Position ringen. Schäffer/Poeschel, Stuttgart

Woll A, Tittlbach S, Schott N, Bös K (2004) Diagnose körperlich-sportlicher Aktivität. Fitness und Gesundheit. Dissertation.de–Verlag im Internet, Berlin

Yagyu S (2007) Das synchrone Managementsystem: Wegweiser zur Neugestaltung der Produktion auf Grundlage des synchronen Produktionssystems. mi-Fachverl., Landsberg am Lech