11. Test at Volvo

Anna DAVIDSSON[1] , Scott LITTLE[2] , Gu VAN RHIJN [3] & Magnus RÖNNÄNG [4]

[1] *Volvo Cars Corp., Research & Development, 405 31 Gothenburg, Sweden*
Tel.: +46 31 325 6211; Fax: +46 31 595924; E-mail: adavid12@volvocars.com
[2] *Swiss Federal Institute of Technology (ETH), Institute of Work Psychology, Nelkenstrasse 11, 8092 Zurich, Switzerland*
Tel: +41 1 632 78 40, Fax: +41 1 632 11 86, E-mail: little@ifap.bepr.ethz.ch
[3] *TNO Arbeid, P.O. Box 718, 2130 AS Hoofddorp, The Netherlands,*
Tel.: +31 23 554 95 88; Fax: +31 23 554 93 05; E-mail: G.vRhijn@arbeid.tno.nl
[4] *Chalmers University of Technology, Product and production development, Human Factors Engineering, 412 96 Gothenburg, Sweden*
Tel.: +46 31 772 5606; E-mail: magr@hfe.chalmers.se

Abstract. This chapter describes the tests of the prototypes of the sociotechnical and selected ergonomic modules of the E/S tool (see Chapter 10) at the Final Assembly shop of the Volvo Cars plant in Torslanda, Gothenburg, Sweden. One section of the production line was videotaped and evaluated according to the E/S tool and the PSIM procedure (see Chapter 7). To test and evaluate the selected modules of the E/S tool two workshops were carried out, one focusing on sociotechnical aspects the other focusing on ergonomic aspects. Both the ergonomic and the sociotechnical modules were well received among the participants. The workshops showed the importance of a participatory involvement of employees when considering ergonomic and sociotechnical aspects of the development process.

11.1 Introduction

Within the PSIM project, the concept and a software prototype of the E/S tool have been developed (see Chapter 10). The E/S tool (Ergonomic/Sociotechnical tool) offers support for ergonomic and sociotechnical analysis and design. The E/S tool consists of a task analysis module, four ergonomic modules (physical workload, process flow, mental workload and safety) and a sociotechnical module. The tool was conceived for participative use, involving multidisciplinary project teams in the analysis and design processes. This chapter describes the tests of the prototypes of the sociotechnical and selected ergonomic modules of the E/S tool at the Final Assembly shop of the Volvo Cars plant in Torslanda, Gothenburg, Sweden.

Two workshops were planned and carried out to test the different modules. In the workshop that focused on ergonomic aspects, the modules physical load and mental load were applied. The safety and process flow modules were demonstrated to the working group, but not actually applied. In the other workshop, the sociotechnical module was tested.

One objective of the tests was to generate ideas for improvements in efficiency and health of a selected part of an assembly line (the unit of analysis) at Volvo, considering physical load and sociotechnical design. The second aim was to evaluate the selected E/S tool modules, thereby eliciting the strengths and the aspects of the E/S tool that need improvement.

11.2 Volvo Cars Corporation

Volvo Cars is a car manufacturer that has gone through large changes during the last decade. The market demands new car models at an increasing speed. Being quite small in global market terms, an effective development process and flexible manufacturing systems that can handle several development processes at the same time as well as producing several products in the same production system are required. To meet these requirements, a flexible organization at the shop floor and an integrated product and process development are needed.

11.2.1 Test Site Description

The unit selected for analysis was a section towards the end of the final assembly, line 1:71. The station 'hanging doors on car' of that line was of main interest for the ergonomic modules.

The reason for this selection was that the same station was previously studied in the 'as is' study in PSIM (spring 2000). Since then it has undergone several changes due to production efficiency projects, which have increased the ergonomic problems. Furthermore, a larger organizational change is planned for the spring of 2002 and preparations for this are ongoing. This coming change was focused on in the tests.

The assembly line of the test site has a length of about 105 meters. The cars move on a conveyer belt at a constant speed that can not be influenced by the operators. The speed of the assembly line was app. 58 cars per hour. There is a day shift (from 6:30 a.m. to 3:24 p.m.) and a night shift (from 3:30 p.m. to 0:24 a.m.).

The test site has about 40 to 45 operators. There are eight different tasks (attaching the doors, attaching the roof rails etc., see table 5.2 for details) being performed on the cars. All operators know all tasks. Every 30 minutes there is a rotation and the operators start working on a different workstation. The operators can call on a resource manager whenever they have a problem or comments to state, e.g. about quality problems of a part that has to be assembled.

The tasks the operators perform on the assembly line are purely manual and highly repetitive. Also, there is hardly any flexibility within the tasks, i.e. when to do the tasks and how to do them.

All operators are included in a KLE team. The KLE team is responsible for quality, delivery, precision and economy and needs to deal with human resources and technology to manage its responsibility. This means that a number of normal support functions are included in the production teams' tasks. To facilitate the teams, there is a support organization, including ergonomics, production engineering, quality, measurements etc.

11.2.2 Ergonomic Work at the Shop Floor

At the final assembly shop, there is one ergonomist, and one full-time employee responsible for work technique. The ergonomic evaluations are done systematically station by station, and also upon requests from operators, production technicians etc. and on basis from rehabilitation statistics. It is also the ergonomists' responsibility to inform and educate on ergonomics for all categories of staff.

Volvo has its own ergonomics standards and requirement specifications, based on Swedish laws but also complemented with new research, former experiences and statistics. The ergonomics data from the factory is all stored in a central database. Once a problem is detected and classified, the problem is discussed and handed over to the production technicians. Even though the ergonomist has no formal responsibility for the solution of the problem from the owner, he/she normally takes an active part in suggesting solutions or work-arounds. For financing, smaller investments can be decided at the basic production engineering level, while larger investments must be cleared at the a higher level.

11.2.3 Development and Ergonomics

During a new car development project, at certain milestones, all aspects of the car are evaluated (including producability and process availability) in parallel. The results are summarized and directions for how to continue the project are derived.

All process related aspects are summarized in a scorecard. For each assembly task, a detailed instruction (PKI) is evaluated on a number of aspects, such as quality, sequence, assembly path, ergonomics and several other parameters. Each parameter in the scorecard is evaluated with respect to current project status. For those parameters not having a satisfactory level, a problem description, solution and deadline is decided. The Manufacturing Engineer (a.k.a. the '*beredare*') is the one responsible for the process related evaluation. To his help he has a variety of simulation tools. But since he does not have the knowledge to evaluate all aspects of the manufacturing system, he has to get help from other 'local experts'. He gathers them at meetings and together they evaluate the parameters and fill in the scorecard.

The development projects have an internal resource for supervising ergonomics when introducing new products or major product changes. Both the beredare and the ergonomist have responsibilities regarding the ergonomics rating on the score card. In general, the beredare sets the initial rating. If the setting is not trivial, he calls for help from the ergonomist. The beredare also has the possibility to use state-of-the-art ergonomy tools, such as computer manikin software. If that is the case, the specified PKI is simulated by a simulation engineer, and the engineer, the beredare and often also the ergonomist and production people e.g an operator or production technichian together reach a conclusion on the basis of the simulation.

Sociotechnical aspects are also considered in the development projects, but not in the same structures way as traditional ergonomics. This responsibility is also the ergonomists'.

11.3 Scenario and Procedure of the Tests

To be able to test in a realistic situation, a specific situation – a scenario – has to be chosen. As large changes were planned for line 1:71, these were addressed as the scenario. The changes are in short:

- A re-organization. The hanging of doors is connected to a new door-line building the whole door, the line will be its own department. Daily rotation between line 1:71 and the door line will take place,
- The new door-line gives a new fixture for transporting the doors with a new lifting tool as a consequence,
- More support functions should be performed by the operator teams as 'new' KLE-teams are implemented (implemented all over the Final Assembly shop).

This scenario of changes was treated according to the process described for process development (see section 11.2.3). The procedure followed normal Volvo evaluation, but takes small steps towards future plans. A wider range of ergonomics and socio-technique evaluations were added through an extended scorecard based on the parameters treated in the PSIM tools. The 'new' parameters were physical load, safety, process flow, mental load, individual work task and work system. The evaluations of the parameters were derived during the test workshops with help of the tools. These new parameters were mainly evaluated on a station or line level, an evaluation level that also was new compared to the instruction level normally used at Volvo.

11.4 The Ergonomic Modules Test

In order to make this test, several preparatory actions were taken by both Volvo and PSIM participants. A preliminary definition of the stations of the assembly line to be evaluated, and setting up a working group to be involved in the test had been carried out prior to the actual test. A procedure was defined and participants were selected.

11.4.1 Preparations

For each workstation in the selected line section, the following activities were performed by an ergonomic expert:

- A video was taken of operators performing their tasks/job. Movements, postures and all activities were all recorded several times,
- Distances (walking, reaching etc.) were measured,
- Operators were asked to do their job as they usually do.

Every workstation was analyzed with help of video, the measurements and the E/S tool. First, the tasks performed at every workstation were listed in the tool. In the next step, every task was analysed with respect to physical load. This was done in the tool using the video for analysing posture, task time, and frequencies. Data from the video and from other measurements were entered into the Ergotool. Risks concerning physical load were also analysed.

11.4.2 Procedure of Group Sessions

The procedure tested at Volvo was the participative part of the tool specific PSIM procedure. The aim of the procedure was to gather all parts with interest in the specific ergonomic issues to be analysed. The procedure used for the group session was in line with the general PSIM procedure.

For the ergonomic module workshop, a mix representing all interested parties was summoned. This included representatives from each of the following groups: Manufacturing Engineer (*'beredare'*), Production technician, Production leader, Operators (two), Verification and simulation expert, Ergonomist, Union safety ombudsman, and Union representative.

After an introduction to the PSIM project, and of the participants and their respective functions, the participants were initiated to the aim of the specific workshop. The different tasks for the line station (1:71) were listed and a problem list for the station was created. Even though a document with problems had already been created by an ergonomics expert, the participatory aspects were valued; hence the choice to recreate the list based on the participants views and comments. Also, not only the ergonomy problems were to be listed, but all problems related to the station. To support the creation of the problem list, a video tape showing the tasks for the station was presented to the participants.

The problems from the problem list were then graded and timed, using the ergonomy modules of the E/S tool. Then, coming changes as well as possible solutions to problems were discussed.

The session was concluded with the filling in of a questionnaire where both the participatory aspects and the Ergotool aspects of the session were to be graded.

11.5 Results from the Ergonomic Module Test

In the following section the results for line 1.71 from the group session and the test with the Ergonomic modules are presented, including examples on the list of tasks, time per worker per day, changes in workstations, problem areas and scores.

11.5.1 Task and Problem Analysis

The zones and activities at the 1:71 line, including the time per worker per day were identified by the working group, see column one and two in Table 11.1. The activities concerning the hood, trunk and suspension were not evaluated in the workshop and are therefore excluded from the list.

Recently implemented changes and daily problems areas were also identified (see column 4 and 5, Table 11.1). At every workstation the most recent Volvo scores were added. Volvo score: load level 1 (green) means: no harmful influence on the body, load level 2 (yellow) means: probably not harmful influence on the body, and load level 3 (red) means: harmful influence on the body. Note: These Volvo scores were identified before the named changes. In column 6, Table 11.1 the physical load scores for workstations 1 to 4 are shown as well.

Table 11.1 Summary of Results from the Ergonomic Modules Test at Line 1:71

Zone time/day	Activity	Volvo eval.	Changes	Problem area	Phys load
1. Tank ***0,5 h/day***	Putting on hoses Filling the tank Taking off hoses	2	Extra activities during filling time (trunk, hood, ..)	'Boring job'	G
2. Liquids ***0,5 h/day***	Putting on hoses Filling fluids Taking of hoses Closing the lids	2	From 2 to 1 person Idea: hoses closer by the car Idea: working technique: step instead of reach	Reaching and pulling Hurry between cars Lids hard to screw Sometimes slippery	Y
3. Roof rails ***0,5 h/day***	Putting on rails across the roof Fastening rails Putting on 3 plastic covers	2+	Station was moved Higher platform Plastic covers are improved From 3 to 2 people	Time pressure when 3 in a row >60° arm elevation for smaller people	Y/R
4. Doors ***4,5-5 h/day***	Attaching hooks Pullinglifting tool Attaching cables Hanging door to hinges Attaching screws Getting machines Tightening screws Putting away machines Measuring/Adjusting doors Putting cables in place Adjusting front door Placing pdf panel Putting off prot. cover	3-,3	From 7 to 6 persons Hinges are changed (higher quality, New fixture for hooks (less adjusting time, less pulling) From 4 to 8 spots to measure 'bonus' work has moved to the line 'button' for swinging door body people measuring door arch line operators doing the rest	Accepting the fixture (attitude, training) Fixture not always work (body/door variation) Fixture must fit in new models Pushing/shaking lifting tool for different angles Twisted/bended posture Pressure on thumbs Time pressure Not much room (new model better) Noise from conveyor	R
4.Front door ***0,5 h/day***	Pulling lifting tool Hanging door to hinges	3-, 3	1 person	Same as above marked in italics, 4. Doors	R

11.5.2 Evaluation on Physical Load, Safety, and Mental Load

The evaluations made in the three ergonomic modules of the E/S tool are presented below. Risks concerning *physical load* were identified in Table 11.2.

Table 11.2 Explanation of the Ergotool Evaluations and Risks Identified

Zone	Physical Load	Overall Score
1. Tank	No problems: green	Green
2. Liquids	Stretching and reaching: bending working posture Gripping and turning lid: arm and wrist load, bended posture, force	Yellow
3. Roof rails	Mounting on or above shoulder level: arm elevation Torque powertool: 6Nm (<2 kgcm in hand), wrist deviation	Yellow (0,5-1 hr a day) Red (whole day)
4. Doors	Trunk rotation, neck torsion and bending Standing on one leg	Red
5. Front door	Trunk rotation, neck torsion and bending Standing on one leg	

Regarding *safety* at the 1:71 line, some risks were identified in the group session, using the Ergotool. Risks were due to noise (sometimes >85 dB(A) at the door station) and temperature (sometimes < 20°C). Other risks were not applicable and the risk of falling was mentioned as very unlikely (green).

Volvo developed a new lifting tool, and a prototype in a lab was tested by the working group. All safety aspects of this new tool were already checked by Volvo. Noise level was supposed to be reduced to 70 dB(A) due to legislation (green).

Mental load in line 1:71 was discussed in the group using a checklist and the Ergotool. The outcome of this discussion is that the work done by a trained operator is experienced as 90% routine based and 10% knowledge based. The knowledge based part can easily increase, for instance when there is a quality problem of parts. If there is some quality problem (for instance roof rails) the operator has to ask for assistance (resource) several times a day. This will increase the mental load. According to the group, operators are mentally occupied for 75% (average) of the work time. For some workstations this is more (100%), for others it is less (50%). This part of the work time requires concentration. The amount of task set switches on every workstation is minimal. The amount of task set switches on every day is 7-8 because of rotating over work stations. The amount of task set switches (disturbances) will increase if there is a quality problem of parts, or during an introduction of a new (lifting) tool, or a new operator etc.

When for instance a new lifting will be introduced, % knowledge based, % time occupied and amount of disturbances (questions of colleagues) will raise during learning time (4-6 weeks). To gain normal speed and to do the job in a skill based way will take 10 weeks. The conclusion is that mental load will rise during learning time. Extra person(s) during that time period could be considered.

11.6 Evaluation of the Ergonomic Modules Workshop

All participants rated the tool as a useful tool not only to improve ergonomics, but also to use as an argument when discussing ergonomics with supervisors.

The participatory process where several individuals with different functions and objectives meet to discuss and develop solutions were considered normal procedure and presented no unfamiliar situation to the participants. Even so, it was considered highly valuable.

Due to technical problems and the status of the ergonomic modules prototype, not many comments about the user interface and the actual implementations were relevant. A few important changes to the tool were suggested, such as a new rating system on the total result of a station. Another important suggestion was feedback to the user: the tool should show why tasks become 'red'. The guidelines should be incorporated in the ergonomic modules. Input parameters as well as the outcome ('borders') must be well defined for the user. Other important issues raised include the qualifications of the user of a future E/S tool, how to define the size of a task and the supervisor´s role in the ergonomic module (merely to introduce the terminology and to instruct on how to build the task analysis. The grading of the tasks can be done without any supervision).

11.7 The STSD Module Test

The STSD module workshop to test the E/S tool at Volvo took place one week after the test of the ergonomic modules. The same Volvo employees participated, i.e. the following roles were represented: One manufacturing engineer ('*Beredare*'), one production technician, one production leader, two operators, one verification expert, one ergonomist, one union safety ombudsman and one union representative.

As mentioned above, the participative involvement of employees for improving the work environment is well adopted and part of the company culture. The participative approach of the STSD module therefore was not unfamiliar to the participants of the workshop. During the workshop that was facilitated by a STSD specialist of the PSIM consortium, the software prototype of the STSD module of the E/S tool as described in Chapter 10 was used.

11.7.1 Problem Definition

After a short introduction of the different participants of the workshop, the first step was to define problems of the unit of analysis that can be addressed with help of the STSD module. Each participant listed the problems that according to his/her opinion were relevant. Together the project team agreed on the following main problems: The implementation of the KLE teams is inadequate, there is insufficient communication between production and management (top down as well as bottom up), the variation in work is low and the integration of the different departments is insufficient. Based on these problems objectives were defined.

11.7.2 Analysis Phase

The STSD module procedure consists of two phases, the analysis phase based on the KOMPASS method [1] and the design and evaluation phase based on the IOR approach [2]. This procedure was applied to define objectives that need to be achieved, to analyze the current situation of the unit of analysis and to evaluate the upcoming changes of the unit of analysis.

Based on the defined problems, the first task of the project team was to define objectives that the unit of analysis should aim at. Every participant had to reflect according to his/her point of view, which objectives should be achieved. To structure the objectives and to assure that the relevant aspects of manufacturing units are considered, the STSD module offers four categories for defining objectives: business management, organization, employees and technology. Based on this analysis the following objectives were defined:

1. Transparent communication,
2. More variation of tasks,
3. Employees have a sense of unity,
4. Motivating tasks.

The objectives were prioritized as listed above. For every objective the project group then had to rate the current situation of the unit of analysis. The assessment of the objectives showed for which objectives the situation is considered worse than for others. The result of this step is important at a later point of the STSD module procedure, where the objectives are related to the module criteria. The objectives and the assessment of the objectives were entered into the STSD module by the workshop facilitator.

Next the basics of the socialtechnical approach were presented and the purpose of the STSD module criteria applied in the next step was explained. The criteria of the STSD module base on the KOMPASS method [1] and are described in Chapter 8. The criteria support the analysis and the design of manufacturing units on basis of the sociotechnical approach. Previous to the test a selection of criteria was chosen for the application at VOLVO. On the level of the work system the criteria independence and polyvalence of the employees were chosen, on the level of the individual task the criteria task variety, planning and decision making requirements as well as influence over working conditions were chosen. For every criterion the STSD module provides a short explanation and a scale for rating the current situation to support the project team in the sociotechnical analysis. For every criterion the project team had to agree on a score representing the current situation and a reasoning of the score therefore integrating the different points of view of the participants.

As a last step of the analysis phase the criteria were related to the objectives. For every criterion the relations to the different objectives had to be defined. The result of this step was a network connecting the criteria to the objectives. This network was central in the next phase for evaluating the upcoming changes in the unit of analysis.

11.7.3 Design and Evaluation Phase

The unit of analysis was about to undergo several major changes. One was that the unit was about to be merged with another related manufacturing unit, the other change was the introduction of a new KLE concept. The focus in the workshop was mainly on the latter point although some aspects could not be analyzed without considering the merger of the two units. As the KLE concept had already been elaborated by VOLVO this concept was analyzed and concretized (instead of the SMWT concept suggested in the prototype of the STSD module).

The new concept of the KLE teams was presented by a member of the project group. The concept had at this point not been concretized yet considering the situation of the unit of analysis. Therefore the project team discussed requirements for a successful implementation of the KLE concept and addressed first steps of concretion.

A basic requirement for a successful functioning of the concept stated was that the operators are provided with a specified amount of time each week for performing the KLE tasks. In addition to the daily official meeting unofficial meetings at lunch would increase the sense of unity of KLE teams. The distinction between the roles of the supervisor, the team leader and especially the resource manager still needed further clarification. The team leader will take over some responsibilities of the supervisor however. The role of the team leader was characterized as follows: The team leader is responsible for the six minutes morning meeting, (s)he knows the skills of the KLE team members and cooperates with other team leaders. Most of his/her daily work however still consists of assembling.

The supervisor's role changes in that (s)he is responsible for communication to higher levels of the organizational hierarchy and is more involved in joint coordinating with other supervisors, thereby focusing more on organizational aspects and long term planning.

The KLE team is responsible for solving problems autonomously and for electing the team leader. The different members specialize on one task but ideally can perform all the tasks within the assembly responsibility.

After analyzing the KLE concept the simulation network developed in the analysis phase was used to evaluate the expected effects of the introduction of the new KLE teams on the defined objectives. Figure 11.1 contains the visualization of the positive effects as presented by the STSD module in the workshop.

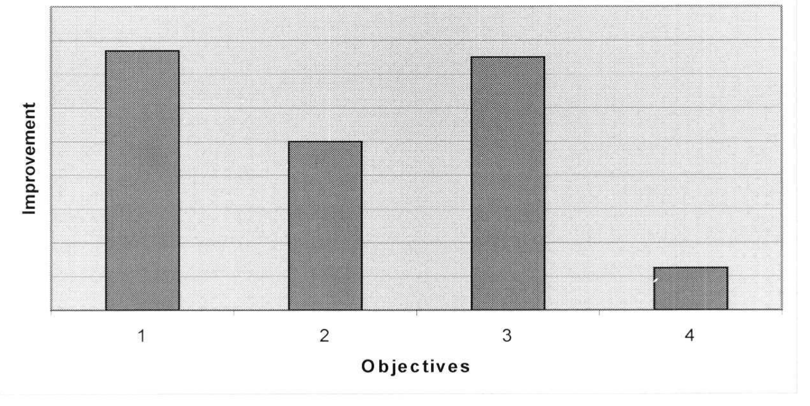

Figure 11.1 Visualization of the Expected Effects of the Introduction of the KLE Teams on the Defined Objectives: 1) More Variation of Tasks; 2) Sense of Unity of the Employees, 3) Motivating Tasks, 4) Transparent Communication

Figure 11.1 shows that the introduction of the new KLE teams is expected to improve the variation of task and the motivation strongly, also increasing the sense of unity but having less a strong effect on the transparency of the communication.

11.8 Evaluation of the STSD Workshop

The aim of the evaluation was to offer the project group the opportunity to comment and to assess the positive and negative aspects of the workshop and of the STSD module. The evaluation was performed after the workshop by means of an open discussion and a questionnaire that was specifically designed for the evaluation of the STSD module. Both sources of information are considered below.

The participative procedure allowed the participants to utilize their knowledge of the work environment, the joint input for analyzing the upcoming changes was considered important.

The criteria of the STSD module were considered interesting, allowing to view the work environment from a sociotechnical perspective. The criteria however were not always easy to comprehend, requiring the support of the workshop facilitator for further explanation. In addition, the time required for applying the criteria was considered too long.

The use of the criteria-objectives network for the evaluation of the new KLE concept was helpful, supporting a systematic approach for evaluating the changes. The changes on the objectives presented by the network coincided with the expectations of the workshop participants.

The project team agreed that the sociotechnical module is suited for analyzing and evaluating present or future changes of production at Volvo. For a regular use however, the module would need to be customized to the needs of Volvo. Once the 'users' would get accustomed to the procedure and the criteria of the module, it could be used on a regular basis for making systematic suggestions for improvements of work organization as well as for evaluating changes.

Important issues raised during this test were the company procedure and based on the evaluation outcome the rules needed for actually implementing suggested changes in production as well as the rules needed for the development process. Another issue was the importance of the workshop facilitator and which person at Volvo could take on that role and what prerequisites would be required for this role if the STSD module were used at Volvo.

11.9 Conclusions

Both the ergonomic and the sociotechnical modules were well received among the participants. They used the modules with great enthusiasm and showed an honest interest in discussing the issues covered by the modules. Both workshops showed the importance of a participatory process when considering ergonomic and sociotechnical aspects of the development process. The tools functioned as IT-based support for the discussions and proved to be very valuable to reach consensus and setting up priority lists for actions.

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References

[1] G. Grote, C. Ryser, T. Wäfler, A. Windischer, and S. Weik, KOMPASS: A Method for Complementary Function Allocation in Automated Work Systems. *International Journal of Human-Computer Studies,* **52,** 2000, pp. 267-287.
[2] L.U. de Sitter, Synergetisch produceren, Van Gorcum, Assen, 1997, (in Dutch).