Evaluation of Battlefield Management Systems

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TNO is a modern Dutch, knowledge-based organisation providing services in the form of research, development and application of new technologies. TNO's knowledge finds immediate and practical use for all clients, both large and small, in the Netherlands and around the world. TNO provides most Dutch government departments with support in formulating policy, and undertakes projects to ensure that the policy works. The Dutch armed forces use the wide range of TNO services and the TNO defence research institutes are even referred to casually as the ministry of defence's in-house laboratory. Battlefield Management Systems (BMS) is one of the programs TNO is involved in.

Before this program will be described, it is important to define the meaning of BMS in the Netherlands. The picture below shows that the Command and Control-Infrastructure in the Netherlands comprises three groups of systems:

- ISIS, the integrated Staff Information System. This is the command, control, communication and information (C3I) system for the level brigade and above.
- BMS, the battlefield management system, the command and control systems for the level of battalion and below.
- SDA, the soldier digital assistant that provides the individual soldier with command and control information.

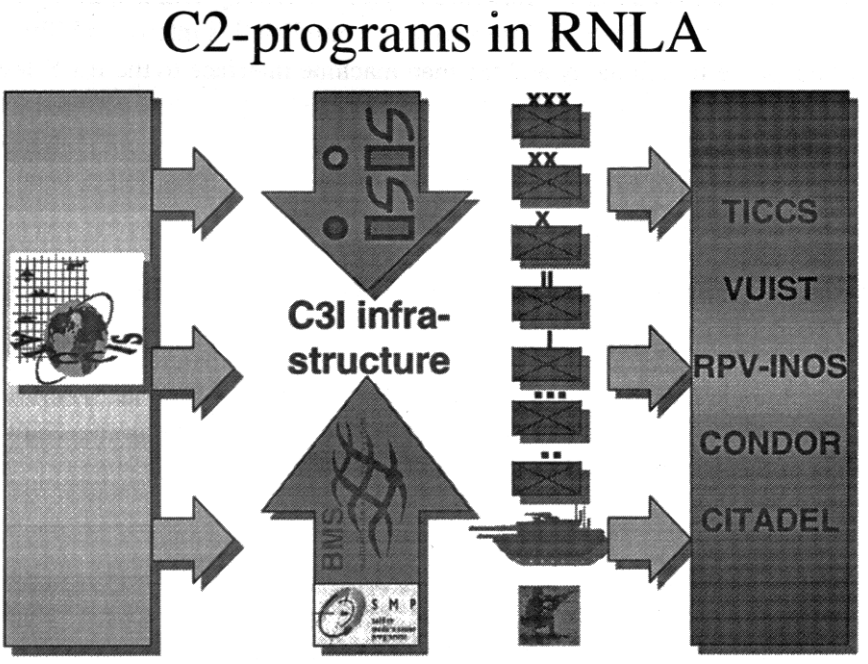

Figure 1: C2-programs in the Royal Netherlands Army

A BMS aims at reaching an optimal situation awareness while striving for maximal combat power, safety and endurance. Situation awareness can be defined as awareness of the current role and status related to friendly, enemy and neutral troops within the relevant part of the operational area. Situation awareness plays a major role in all decision processes.

The first phase of the Dutch Battlefield Management Research and Development program started in 1996 when the Royal Netherlands Army (RNLA) awarded TNO a contract to investigate the phenomenon BMS. The attention for BMS was coupled to the introduction of a new German-Dutch Reconnaissance Vehicle in 2001 (The Fennek). Although this platform will most likely be the first one with a fully integrated BMS, the BMS-study is not limited to this platform. The ultimate goal is that all operational units in the RNLA, starting with the reconnaissance, will have a BMS.

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Among other things, the first phase led to a global list of functionality's and an identification of relevant developments in the international defence community. One of the outcomes of this study was the TNO-advise to evaluate a number of commercially available BMS's. It was advised by TNO to evaluate the systems in a laboratory environment.

The purpose of this evaluation was twofold: first of all it would have to assess the systems as a possible solution for a Dutch BMS; secondly, the evaluation would help to refine the requirements of the BMS obtained in the first phase.

The reason for an evaluation in a laboratory environment was:

- to save money compared to a complete field trial with the system
- get a strong focus on functionality and man-machine interface
- get a quick picture of the suitability of the available systems
- get a quick start with the specification of requirements

At the time of the decision, two systems were commercially of the shelf available: FINDERS® of GIAT Industries and DIFA of STN ATLAS. Both systems were evaluated in exactly the same way. This paper describes the approach that was taken during the evaluation and the methods that were used to describe the functional, technical and design features of the evaluated systems. We will not describe the actual conclusions with respect to the content.

One of the requirements for the Dutch BMS is the ability to exchange information with the higher level Command and Control system ISIS (Integrated Staff Information System). This system is built by the RNLA in co-operation with TNO and other industries. One way to accomplish this interoperability is by using components of ISIS and adapt the functionality and the man machine interface to the BMS-level. For this reason ISIS was the third system to be evaluated. The evaluation of ISIS slightly differed from the evaluation of FINDERS® and DIFA, due to the fact that ISIS is not a BMS and only components of this systems might be used. The evaluation of FINDERS took place in December 1996, DIFA was evaluated in March 1997. ISIS was subjected to our tests at the end of 1997.

The evaluation comprised 5 blocks: Training, Functional evaluation, Technical Evaluation, Scenario Evaluation and Discussions. In order to cover military operational, human factor as well as technical aspects of the evaluated BMS, a team has been set up consisting of military reconnaissance and main battle tank experts of the RNLA, human factors experts and technical experts. The total team comprised 7 people and was constantly supported by the suppliers. The combination of the people in this team assured that all relevant aspects of the system would be given a chance. Neither of the companies ever subjected their systems to a team like this.

The evaluation has been performed on behalf of and in close co-operation with the BMS-projectteam of the RNLA. Representatives of this group attended several sessions of the evaluation to give a valuable contribution from the operational context to the experimental sessions and discussions.

Below, each of the 5 blocks of the evaluation will be described. After these 5 blocks, there is a section which describes the way the results were presented and a section with the conclusions and recommendations.

Training

The training block was incorporated to get used to the system and to get an overview of the functions offered by the system. The time needed to reach this goal was three days for each system. At the end of the training session, each participator should have a clear understanding of the basic concept of the system and should be able to find the most important functions without assistance. In this way the functional and scenario evaluation will not be hindered by lack of knowledge of the system.

This block also included the set-up of a function overview that could be used as the guideline to execute the functional evaluation. The main question for this set-up was how the functional evaluation can be done in a structured manner that results in a complete overview of the functions and gives a detailed view of how the functions can support the reconnaissance task.

In general one can take two approaches. One can take the system with its function as the starting point or one can take the soldier with it's task as the point of departure. With the first functional approach you evaluate a function and try to find out which tasks are supported by this function. You will probably find out that there are functions that do not support any tasks. With the second task oriented approach you evaluate a task and try to find out which functions can support this task. Both approaches have clear advantages and disadvantages. The functional approach leads to a very thorough understanding of the functions, but will perhaps fail in delivering a good understanding about what this function means for the reconnaissance tasks. The task oriented approach will solve this problem, but might split up the evaluation of functions in to much pieces.

The solution for this dilemma is a simplified C3I-model that divides the functions of the BMS into four groups of logically related functions. The groups are *Command*, *Control*, *Communication* and *Information*. Each group consists of functions or sets of functions that are logically related in the sense that they are usually performed together.

Below you will find the simplified C3I-model.

COMMAND • Receive / Check / Interpret order • Compose / Send order • Adapt / Send order • Send feedback information • Receive feedback information	COMMUNICATION • Initialise / Manage communication network • Know what you sent / received / saved • Know to whom and from whom messages were send and received • Manage your mailboxes
CONTROL • Check equipment status • Compose / Send status report • Receive / Check / Interpret status report • Compose / Send request for fire support • Receive / Check / Interpret request for fire support • Compose / Send request for logistic support • Receive / Check / Interpret request for fire support • Plan / Plot / Control Route	INFORMATION (SITUATIONAL AWARENESS) • Report observations • Compose / Send alerts • Receive / Check / Interpret alerts • Compose / Send situation reports • Receive / Check / Interpret situation reports • Monitor friendly/hostile positions / movements / actions • Monitor environment (geogr., meteo., NBC, ...)

This simplified model is based on the command & control functions that we currently find in the available BMS's.

Functional evaluation

During the functional evaluation we tested the functions separately or in logically related groups in accordance with the simplified C3I-model. The goal of this block is to get a detailed description of a representative or complete selection of the functions offered by the BMS's. This was used to refine the global functional requirements that were obtained in the first phase of the program as well as a means to come to a conclusion about the suitability of the evaluated BMS as a basis for a Dutch reconnaissance BMS. The functional evaluation took two days.

Two forms were used for the functional evaluation. One that has to be filled in for each evaluated function and one that has to be filled in once after completing all functional evaluations. The first form basically specifies the strong and weak points of the functions in relation to the reconnaissance task these functions were meant for. It also contains an overall rating that the user can assign to the (group of) function(s). Each participant had to fill in the form. In this way we got the expert vision of technical, human factors and operational military experts. You will find this form in Appendix A.

The second form gave the evaluators the opportunity to specify some of the more general problems they experienced while using the system. This list is based on a method of Ravden and Johnson [1]. This method is used for software systems in general and is in particular useful for software systems that have to be used in military environments that are time critical and where the main job is not using the computer but fulfilling some kind of military operation under mostly difficult circumstances. You will find this form in Appendix B.

There are several aspects that are not function-specific and/or did not fit in the evaluation of a specific evaluation step. An example of this is map scrolling. We paid special attention to these points during the second day of the function evaluation.

Scenario Evaluation

During the evaluation of the functionality, there was a strong focus on functions or sets of functions. Although this evaluation was done with the reconnaissance tasks in mind, there was a risk that information would be missed about the support that the BMS gives the reconnaissance unit during the preparation and execution of a reconnaissance mission. For instance, during the functional evaluation, not much information about the situation awareness was acquired, like the visibility of contact alerts that were received. This is because every step in the function evaluation was planned in advance and lacked the element of surprise.

For this reason, we designed a scenario of a reconnaissance mission that could be played during the evaluation. Of course, one had to take into account the restrictions of a laboratory environment without a real (or computer simulated) enemy. Nevertheless, we expected to get information about the operational usefulness of the system during this evaluation step.

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[1] Ravden, S. and Johnson, G. Evaluating usability of human-computer interfaces: a practical method. Ellis Horwood Limited, Chichester, England. ISBN 0-7458-0614-7 (1989)

In order to get a realistic script, we designed the scenario in co-operation with military reconnaissance experts. The mission used in this scenario was a reconnaissance of an area with roughly a width of 10 km and a depth of 20 km. The mission was part of a brigade's intended advance to contact. We divided the mission in a mission-preparation phase and a mission-execution phase. The roles of the platoon commander(PC), group commander(GC), vehicle commander(VC) and squadron commander (SC) were played. With the representation of these roles, a scenario could be designed that pays attention to different communication and co-ordination aspects, situation awareness and the information needs of different command levels.

The events that occurred during the scenario were simulated by cards. There is a set of cards for each player. The cards are handed to the player by the scenario leader. A card contains all the necessary information about the event that took place. So, instead of the first contact with an enemy vehicle, the player got a card describing this event with information like position, direction of movement and actions of the enemy that was spotted.

In order to avoid 'unnatural' contact between the players, the players were separated from each other by a wooden partition. The only way to communicate with each other was via the BMS or via the voice radio. Of course this could only take place in accordance with the appropriate protocols. For instance, if a certain situation in the scenario enforced a radio silence periods, no voice communication was possible. Without this restriction the participants would have been able to communicate with each other about system specific items that would normally not occur like 'did you see the message I send you' or 'you should use the right button to perform this specific action'. This kind of communication would infuence the reliability of the results of the evaluation.

A complete description of the scenario can be found in Appendix C. The playing of this scenario occupied one full day and was attended by the complete evaluation team as well as three engineers from the company that delivered the BMS. The tasks of the scenario were divided into four scenes. For each scene the evaluators had to fill in one form as displayed in Appendix D.

Technical evaluation

During the technical evaluation we looked at all kinds of technical issues like (software) robustness, backup and recovery and the connection to the combat net radio's, including the protocols that were used to send and receive messages. Most of the technical evaluation was done by discussing about it. Only a few tests were performed like switching of the system (in several ways, for instance by unplugging all kind of cables) and recovering form this event. We did not pay attention to hardware robustness, since this can only be done in a real environment.

The discussions were used to present our first impressions and to get more insight in all kind of choices that were made by the supplier. Also, these discussions were used to get more information about the abilities of the system to exchange information with higher level C3I-systems.

Presenting the results

The results of the evaluation were presented to the RNLA in a report. An important part of this which is interesting in this context is the part where the results of the functional and scenario evaluation is presented. For evaluating the data obtained from the functional and scenario evaluation, a framework of well-known Human-Computer interaction software ergonomics criteria as set out in Ravden & Johnson [2] was used. These criteria are visual clarity, consistency, compatibility, informative feedback, explicitness, appropriate and missing functionality, flexibility and control, error prevention and correction, and user guidance and support. The data have been examined from all these viewpoints. The resulting information has been organised along six more task-oriented lines. The main findings of the computer-user interface evaluation have been summarised in tables like the one in Appendix E..

There are six tables for six categories. The tables give a very quick impression of the evaluation results and also gives the possibility to compare systems with each other.

The first category of findings concerns system configuration and control of the system (the example given above), the second map presentation and functions, the third tactical information presented on the overlays, and in the fourth category communication issues are discussed. The fifth section concerns automatic updating functions. In the sixth section a rating of the input devices can be found, and the last section contains information on the display. These findings must be interpreted within the tasks and functions that could be carried out with the system in a laboratory setting, and cannot be generalised to the fully operable system. Although the set-up allowed the evaluation of planning and message handling functions, the evaluation of situation awareness definitely suffered from the lack of a real setting with the BMS connected to platforms and possibly a higher-echelon C2 system.

In the report, the summary of findings of the user and scenario evaluation is followed by a very detailed descriptions of all the results. With a lot of examples, the strong and weak points of the system are described.

Conclusions and recommendations

The evaluation process of the BMS's has given insight in the potential applicability of the system for the Dutch reconnaissance units and the Fennek in particular. It also resulted in obtaining experiences in order to refine the functionality's as expressed earlier by the Dutch Army Staff. However this evaluation was performed under the restrictions of a laboratory environment and therefore did not touch operational and sensor integration aspects.

Based on the results of the evaluations a choice has been made to use components of the Dutch ISIS-system and Commercial of the Shelf components for the design and implementation of a pilot BMS system. The goal of this pilot system is to come to the final functional and technical requirements of a Dutch BMS system. In the first version of this pilot system the recommendations of the laboratory evaluation will be processed. The intention is to reach this goal by organising a number of field trials and involve the end-user in these field trials to refine the requirements in a number of steps. After each experiment the pilot system will be adapted to incorporate the new requirements that are obtained. The experiments will begin on the scale of a platoon and end on a battalion scale. All units used for the experiments will be reconnaissance units. However the pilot system will consist of a generic part that can be used for all kind of units and a specific reconnaissance part. Beside this, each kind of platform that is involved can have a different manifestation.

After the pilot phase, the industry will have to be involved to build an operational version of the BMS. The pilot phase only serves as a vehicle to get the final requirements.

In addition to the pilot project, a modelling and simulation path has been started to evaluate sensor integration aspects and ergonomic aspects of the use of a BMS in the Fennek vehicle. TNO has taken preliminary steps with respect to the facilities in her laboratory to accommodate such a study.

During the coming year TNO will be heavily involved in the pilot project and the modelling and simulation path. Both projects will be performed in close co-operation with the BMS-projectteam of the RNLA.

Appendix A: FUNCTION EVALUATION FORM

USER NUMBER	
TASK DESCRIPTION	
TASK PRIORITIES	

QUESTION NUMBER	COMMENTS

STRONG POINTS	WEAK POINTS

MISSING FUNCTIONALITY

SYSTEM RATING				
unsatisfactory	moderately unsatisfactory	neutral	moderately satisfactory	satisfactory

Appendix B: SYSTEM USABILITY QUESTIONAIRE FORM

	Usability category	Problems		
		none	minor	major
1.	Working out how to use the system			
2.	Lack of guidance on how to use the system			
3.	Poor system documentation			
4.	Understanding how to carry out the tasks			
5.	Knowing what to do next			
6.	Understanding how the information on the screen relates to what you are doing			
7.	Finding the information you want			
8.	Information which is difficult to read clearly			
9.	Too many colours on the screen			
10.	Colours which are difficult to look at for any length of time			
11.	An inflexible, rigid system structure			
12.	An inflexible HELP (guidance) facility			
13.	Losing track of where you are in the system or of what you are doing or have done			
14.	Having to remember too much information while carrying out a task			
15.	System response times that are too quick for you to understand what is going on			
16.	Information which does not stay on the screen long enough for you to read it			
17.	System response times that are too slow			
18.	Unexpected actions by the system			
19.	An input device which is difficult or awkward to use			
20.	Knowing where or how to input information			
21.	Having to spend too much time inputting information			
22.	Having to be careful in order to avoid errors			
23.	Working out how to correct errors			
24.	Having to spend too much time correcting errors			
25.	Having to carry out the same type of activity in different ways			

Appendix C: The complete scenario description

A Dutch reconnaissance platoon consists of three groups of two vehicles (A/B, C/D, E/F) and one commander vehicle (R) with the Platoon Commander (PC). The groups are named after its first vehicle (A, C and E) and are leaded by a Group Commander (GC). The individual vehicles are leaded by a Vehicle Commander (VC). The platoons are part of a squadron with a Squadron Leader (SC). In this case, the squadron will be part of a brigade. This type of squadron consist of 2 reconnaissance platoons and one platoon of skirmishers (First, Second and Third platoon).

The mission used in this scenario will be a reconnaissance of an area with roughly a width of 20 km and a depth of 30 km, east of the city Amersfoort. The reconnaissance will be executed by the first platoon and the second platoon, side-by-side. (The second platoon operates south of the first platoon). The reconnaissance mission will be part of an intended advance to contact a brigade. The goal of the mission is to make sure that the area is clean for the advance of contact. Of course, a number of observation posts will be set up at the utmost limit of the reconnaissance area.

We will divide the mission in a mission-preparation phase and a mission-execution phase. The role of the PC, GC and VC will be played. Occasionally, the role of an SC will be played While running the scenario, we will regularly pause to evaluate.

MISSION PREPARATION (SCENE I)				
NR	**FROM**	**TO**	**ACTION**	**ACTION BY SCENARIO LEADER**
P1	SC	R	distribute KVPOG[2] by MIDAT.	Load KVPOG in MIDAT.
P2	R	A/C	distribute KVPOG.	
P3	SC	R	distribute order by MIDAT.	Load squadron plan in MIDAT.
P4	SC	R	Verbally explain paragraph 3 (combat plan) of NATO standard order.	Explain combat plan verbally.
P5	R	A/C	send NATO standard order.	-
P6	R	A/C	Verbally explain paragraph 3 (combat plan) of NATO standard order.	-
P7	R	A/C	Ask for Function Control 1 (FUCO-1).	Give CARD-R1.
P8	A/C	R	Pass result of FUCO-1.	-
P9	A/C	R	Pass detailed group plan.	-
P10	-	-	Reject detailed group plan of C.	Give CARD-R2 with info about rejection.
P11	R	C	Pass changes of detail plan of C.	-
P12	SC	R	Pass latest information about enemy and terrain.	Load latest enemy/terrain info in MIDAT.
P13	R	A/C	Pass latest information about enemy and terrain.	
P14	-	-	Fill in evaluation form	Give evaluation form to A, C and R

[2] KVPOG is a Dutch abbreviation for: coming action, the movement, expected time and place of orderreceiving, The higher command level and the level of combat readiness. Consider this as a warning order.

MISSION EXECUTION (SCENE II)				
NR	**FROM**	**TO**	**ACTION**	**ACTION BY SCENARIO LEADER**
E1	-	-	R, A and C in start position.	Move Vehicles to R1, A1, C1.
E2	C	R	Arrived at object, perform dismounted reconnaissance.	Specify by CARD-C1. Vehicles at R1, A1, C1.
E3	-	-	-	Move Vehicle to R1, A2, C2.
E4	C	R	No peculiarities at object.	Give CARD-C2.
E5	A	R	Enemy alert (VIJ-1).	• Location (VIJ-1) by simulation. • Kind of enemy (VIJ-1) by CARD-A1. Vehicles at R1, A2, C2.
E6	A	R	Artillery request on enemy (VIJ-1).	Give CARD-A2.
E7	A	R	Cannot reach Southside of village.	Give CARD-A3.
E8	R	C	Reco. Southside of village.	Give CARD-R3.
E9	-	-	Artillery fire destroys enemy (VIJ-1).	Give CARD-A4.
E10	-	-	-	Move Vehicle to R2, A2, C3.
E11	A	R	Passing results of Artillery Fire.	Give CARD-A5.
E12	-	-	-	Move Vehicles to R2, A2, C4.
E13	C	R	Southside village free of enemy.	Vehicles at R2, A2, C4.
E14	-	-	Fill in evaluation form	Give evaluation form to A, C and R

MISSION EXECUTION (SCENE III)				
NR	**FROM**	**TO**	**ACTION**	**ACTION BY SCENARIO LEADER**
E15	R	A/C	Continue with mission on original route.	Give CARD-R4.
E16	-	-	-	Move Vehicles to R3, A3, C5.
E17	-	-	-	Move Vehicles to R3, A4, C6.
E18	A	R	Enemy alert (VIJ-2).	• Location (VIJ-2) by simulation. • Kind of enemy (VIJ-2) by CARD-A6.
E19	A	R	Pass information about minefield.	Give CARD-A7 (location and area).
E20	-	-	-	Move vehicles to R3, A4, C6.
E21	C	R	Arrived at object, perform dismounted reconnaissance.	Give CARD-C3.
E22	-	-	-	Move Vehicles to R3, A4, C7.
E23	C	R	No peculiarities at object.	Give CARD-C4.
E24	-	-	Fill in evaluation form	Give evaluation form to A, C and R

MISSION EXECUTION (SCENE IV)				
NR	**FROM**	**TO**	**ACTION**	**ACTION BY SCENARIO LEADER**
E25	R	A	A has to use object of C to continue original route.	Give CARD-R5.
E26	-	-	-	Move Vehicles to R4,A5, C8.
E27	C	R	• Vehicle D hit by enemy and is in fire. • Enemy (VIJ-3) location unknown.	Give CARD-C4.
E28	R	C	• First aid to crew of Vehicle D. • Determine enemy (VIJ-3) location.	Give CARD-R6.
E29	R	A	Try to get information about enemy (VIJ-3).	Give CARD-R7.
E30	C	R	• Vehicle D cannot be used anymore. • Driver most likely killed / Commander seriously injured, urgently needs medical help. • Enemy (VIJ-3) location unknown.	Give CARD-C5.
E31	-	-	-	Move Vehicles to R4, A6, C8.
E32	A	R	NBC-1 detection alarm.	Give CARD-A8.
E33	R	A	Perform NBC detection.	Give CARD-R8.
E34	A	R	Send NBC-3 (detection report).	Give CARD-A9.
E35	-	-	-	Move Vehicles to R3, A6, C8.
E36	R	A/C	Pass: had consultation with SC. Enemy pressure to big. Take into account the arrangement of observation posts on westside of A-30 (highway). Observation sectors will follow.	Give CARD-R9.
E37	R	A/C	Pass observation sectors.	Give CARD-R10.
E38	-	-	-	Move Vehicles to R4, A4, C6.
E39	A/C	R	Pass actual observation sectors.	Give CARD-A10 and CARD-C6.
E40	-	-	Fill in evaluation form	Give evaluation form to A, C and R

Appendix D: SCENARIO EVALUATION FORM

DATE	
MISSION PHASE	
MISSION STEPS	
ROLE	
OPERATIONAL TASK	
FUNCTIONALITY / SUPPORT REGARDED AS ADEQUATE	
FUNCTIONALITY / SUPPORT THAT NEED IMPROVEMENT / CUSTOMIZATION	
BMS FUNCTIONALITY AND SUPPORT THAT IS MISSING	

SYSTEM RATING				
very unsatisfactory	moderately unsatisfactory	neutral	moderately satisfactory	very satisfactory

Appendix E: Main findings of System Configuration and Control

category	rating	remarks
System Configuration and Control		
Functional compatibility with RNLA reconnaissance tasks		
Transparency: ease of learning, understanding and using		
Suitability of system for planning and action preparation		
Suitability of system for action execution		
Access to system functions and their organisation along function keys and menus		
Guidance of user		
Indication of settings, state, messages and warnings		
System response times		
Back-up facilities for information recovery		
Saving of selected information		
Query capability		
Printing facilities		