A METHOD FOR COMPARING MILITARY HQ INSTANTIATIONS

Leanne Mary Laidlaw Rees
Land Operations Division
Defence Science and Technology Organisation
PO Box 1500, Salisbury SA 5108, AUSTRALIA
leanne.rees@dsto.defence.gov.au
Phone: +61 8 8259 5238, Fax: +61 8 8259 5624

and

Fred D.J. Bowden
Land Operations Division
Defence Science and Technology Organisation
PO Box 1500, Salisbury SA 5108, AUSTRALIA
fred.bowden@dsto.defence.gov.au
Phone: +61 8 8259 5205, Fax: +61 8 8259 5624

Abstract

This document provides a simple generic method on which to base the comparison of system instantiations[1]. The method is an efficient and cost effective technique that is particularly suited to the investigation of a variety of situations such as the introduction of new technology, command and control issues and system restructuring. The method proposed was developed from a necessity to undertake evaluations of complex military systems, in particular associated with command and control. A military headquarters is used as an example of how the method can be applied. A number of system instantiations are discussed, showing the impact of introducing new technology into a military headquarters at a brigade level.

1. **Introduction**

The System Instantiation Comparison method uses an amalgam of systems engineering and soft systems analysis ([Checkland, 1993], [Kearney, 1998], [Lane and Galvin, 1999], [Hunt *et al.*, 1999] and [Finegan, 1994]). The method presented takes a complex social and technological system, defines the system under consideration, allows the system to be exercised, quantifies its performance, and allows comparison of multiple instantiations with minimum effort. It also provides a capability to estimate cost factors associated with the system. These capabilities combine to enable the impact of advanced technologies and process changes within the system under study to be evaluated.

[1] An instantiation of a system is a particular variant of the system.

The method was developed through a requirement to provide a simple, flexible and cost effective approach to evaluation of command and control systems. However, the method can be ported to the examination of a broad class of systems that are not necessarily military, for example biological systems [Bowden and Rees, 2000]. A military headquarters, that is the centre for command and control, is used in this paper as an illustrative example of how the method can be applied.

Initially this paper gives a very brief overview of the system instantiation comparison method. It then applies this method to the analysis of a military headquarters, using this example to further illustrate how the system instantiation comparison method works. Finally the direction of future work is outlined.

2. **Overview of System Instantiation Comparison Method**

The method proposed, defines a generic and simple model within which the system under investigation is described, and a structure on which to base evaluations. The model describes the system under investigation with three components: the systems critical component, system functions and system enablers.

The critical component is the essential element of the system, that is, the key requirement of the system for it to achieve its operational objectives. The functions undertaken by the system utilise this critical component to achieve the operational outcomes expected of the system. The way in which the system carries out and supports these functions is defined in terms of the systems structure, mechanisms and resources, which are grouped as system enablers. These components define the operations of a system and its accompanying cost. How the system is defined in respect to these three aspects is illustrated in the following section.

The evaluation is conducted via comparisons of different instantiations of the system. Between each instantiation the critical component and system functions are static, while the enablers are dynamic. It is this dynamic aspect of the system that provides the unique basis on which to vary the system enablers to provide quantitative comparisons between the system instantiations. In broad terms the method asks the question “How well does this instantiation of the system enablers allow the system functions to utilise the critical component?”. A more detailed definition of the system instantiation comparison method can be found in [Bowden and Rees, 2000].

3. **System Instantiation Comparison Method Applied to Command and Control**

The primary role of a military headquarters is to provide command and control to its subordinate elements facilitated through the use of information, so that the whole military formation can operate in the most effective manner. As discussed in [Grinde-Roger and Hesser, 1990], information is considered a driver for the effective operation of a miliary headquarters. The commander uses this information to make decisions that control the forces. The speed of making a decision should not in itself be the ultimate goal of the headquarters. What is likely to be of more importance is the “quality and timeliness” of decisions. It is not sufficient to make a faster

decision that is incorrect, it needs to be a quality decision in the appropriate time frame. Thus a study of timeliness alone does not determine how well the overall system is operating. To achieve information superiority, commanders must have access to information that is sufficient, current, consistent and flexible in nature. They need to have access to information in the desired format at the desired time. High fidelity and sufficiency of the information are key attributes, which will help manage uncertainty related to the battlefield as outlined in [Grinde-Roger and Hesser, 1990].

The introduction of advanced information management can enhance the performance of command and control systems. Central to the performance of the command and control system is the capability to provide a common, coherent and accurate picture of the environment to the appropriate command elements allowing the basis for decisions and management actions associated with the battle, as shown in [Nobel and Wheatley, 1999]. Also highlighted, is that the introduction of information technology offers the potential for advancement in war fighting capabilities. However, these technology advancements by themselves do not necessarily relate to an increase in military effectiveness. The technology must be employed within suitable supporting training, organisational structures and concepts of operations.

3.1 ***Application of the System Instantiation Comparison Method to a Military Headquarters***

A military headquarters epitomises the concept of a complex system. Introducing new technologies may add further complexity, resulting in changes to the processes and cultural aspects of the headquarters. It therefore poses a challenge for evaluation in terms of generically defining the headquarters as a system, and providing a flexible and cost effective framework to conduct comparison between proposals.

Future command and control environments could be drastically changed by the introduction of new technologies. However, the basic role of the headquarters and what it is required to do will not change. That is, the critical component and functions will not change despite the potential to radically change other aspects of the headquarters.

3.1.1 ***Defining the Components of the Method when Applied to a Miliary Headquarters***

The critical component of a military headquarters is information. In understanding the information requirements of a headquarters it is necessary to break the critical component into sub-categories called critical characteristics. These represent the key information requirements to perform the headquarter's functions. The critical characteristics are the generic set of the commanders critical information requirements. As supported by [NATO, 1998], [Australian Army, 1996], [Grinde-Roger and Hesser, 1990], [Hesser, 1991], [Lane and Galvin, 1999], [Nobel and Wheatley, 1999] and collected military exercise data, they are applicable across all scenarios and can be extracted from the standard messages. It is proposed that this data is all that is needed to make decisions within the headquarters and all data that flows in and out of the headquarters fits into one of these categories. These categories are generic in nature and independent of level of command, and essentially define the data required to obtain situational awareness in the

battlespace. The authors have determined that for a military headquarters critical characteristics are (listed in no particular order):

- Opposition forces identity, location, status, intent
- Neutral forces identity, location, status, intent
- Own forces identity, location, status, intent
- Weather
- Topography

Key activities undertaken by the system are defined as the system functions. These functions provide the headquarters system with the ability to understand the environment to monitor, understand, predict, control, direct and visualise. The functions are considered generic to a military headquarters and represent all their operations. For the military headquarters under consideration the functions are defined as plan, assess, monitor the battle, execute and message distribution.

The focus of these functions is towards monitoring, understanding and to some extent controlling the environment. Once the environment is understood, informed assessments can be made, hence it is assumed that timely and quality decisions can be taken and execute. This then forms the generic basis for defining the functions associated with headquarters operations[2]. These functions provide the required information to the decision maker and the command and control processes that enable assessment, planning and execution, thus defining the system functions. The functions associated with command and control are discussed further in [Kearney, 1998].

For a military command and control system, such as a military headquarters, the system enablers associated with resources, structure and mechanisms provide a representation of how well the system manages the information. That is, its ability to interpret, manipulate, access and communicate information internally within the sub-system and between systems.

System Resources

System resources enablers can be used as a basis to estimate of the cost of the system. Some examples of system resources for a command and control system are training, staffing and infrastructure.

System Structure

The system structure enablers provide the capability of the system to transfer and access information within or between sub-systems. Three military headquarters structure enablers are the ability to access, interrogate and transfer information.

System Mechanisms

The system mechanism enablers are the ability of the system to manipulate and interpret the information. Grinde-Roger and Hesser give mechanisms associated with the identified information, although referred to by Grinde-Roger and Hesser in [Grinde-Roger and Hesser,

[2] The generic nature of the functions of a command and control system, regardless of the technology or the doctrine is supported by [Grinde-Roger and Hesser, 1990] and [Kirzl, 1998].

1990] as characteristics. It is proposed to extend the list. The modified list includes the presentation, filtering and fusion of information.

The variations in the system instantiations considered in this example result in changes in all three enablers. For example, the second instantiation introduces a global positioning system resources to units so the position information can be passed to the headquarters. The third instantiation also introduces further computing power into the headquarters to process the extra location data. The next section will detail the changes to the structure and mechanisms of the system between instantiations.

3.1.2 ***Evaluation of A Military Headquarters***

To illustrate the method, three instantiations of a system will be compared. What will be investigated is the impact of enhancing the information on own locations in a headquarters at brigade level through the introduction of new technology. The first variant will be considered as the base instantiation. In the second instantiation, the change will be in the form of regular automated updates of own locations. Instead of receiving own locations every 2 hours own location will be automatically sent every 10 minutes from a global positioning system attached to each of the sub-units. These locations are then manually added to the battlemap. In the third instantiation this data will be automatically placed on a digital battlemap along with the introduction of appropriate supporting infrastructure, staffing and procedures to accommodate the introduction this technology . Thus the overall effect of both instantiations is more regular and accurate information about own forces locations.

Note that, for the example considered here, neutrals, identity or weather information are not included in the analysis, and the functions planning, assessment and execute are assumed to be most affected. This will help to simplify the explanation of the method. Note in the plan and assess functions, the information elements are transferred and accessed internal to the headquarters, while the execute function is reliant on the ability to access and transfer information external to the headquarters. This is to simplify the illustration of the system instantiation method. Note that for this example all the values are artificial due to security implications.

The method is facilitated via the population of an aggregation table as shown in Table 1. This table provides an illustration of the analysis of data for the first variant representing the base instantiation.

The critical characteristics used in this example are defined as the “information characteristics” and are listed in the left had column of the table, (opposition location, opposition status, opposition intent, own location, own status, own intent, and topography). Weightings associated with the critical characteristics are identified in the “weight” column of the table. These determine the criticality of the characteristics to the given functions. For a headquarters, the critical characteristic weights can be determined using the criticality index as defined in [Hesser, 1991]. This allows for the calculation of the weights using their perishability, frequency and

importance. An alternative technique would be to use the analytic hierarchy process [Saaty, 1990], allowing subject matter experts to rank the critical characteristics for each function.

Table 1 Evaluation for the First Instantiation

	FUNCTIONS											
	Planning				Assessment				Execute			
Function Weight	0.2				0.6				1			
Information Characteristics	Weight	E1	E2	Weighted Function Measure	Weight	E1	E2	Weighted Function Measure	Weight	E1	E2	Weighted Function Measure
Opposition Location	0.8	0.5	0.5	0.16	1	0.5	0.5	0.6	0.8	0.5	0.5	0.8
Opposition Status	0.5	0.5	0.5	0.1	0.6	0.5	0.5	0.36	0.7	0.5	0.5	0.7
Opposition Intent	0.7	0.5	0.5	0.14	0.7	0.5	0.5	0.42	0.7	0.5	0.5	0.7
Own Location	0.8	0.5	0.5	0.16	0.9	0.5	0.5	0.54	1	0.5	0.5	1
Own Status	0.6	0.5	0.5	0.12	0.6	0.5	0.5	0.36	0.4	0.5	0.5	0.4
Own Intent	0.9	0.5	0.5	0.18	0.4	0.5	0.5	0.24	0.4	0.5	0.5	0.4
Topography	0.8	0.5	0.5	0.16	0.3	0.5	0.5	0.18	0.8	0.5	0.5	0.8
Cross Characteristic Function Measure				1.0				2.7				4.8

System Measure	**8.5**

The system "functions" (planning, assessment and execution) are listed across the top of the table. The function weights listed across the top of the table as "function weight", determine the criticality of the functions to the system. Again, the analytic hierarchy process could be used to calculate these weights.

Two values are used to relate the types of system enablers to the system measure. These are identified as structure and mechanisms. The values relating to the system structure measure are given as the "E1" values in the tables. The system mechanisms measure values are given as the "E2" values in the tables. These values relate to how "well" the instantiation currently being evaluated allows the functions to utilise a specific information characteristic. It is these numbers alone that will vary between instantiations. For the analysis given in this paper a variety of

subject matter advisers were asked for their impressions and rankings using survey techniques as described in [de Vaus, 1995][3].

The function weight ("function weight"), information characteristics weights ("weight") are used, along with the system enabler values ("E1" and "E2"), to determine the "weighted function characteristic measures" this describes how well the function can utilise the critical characteristics taking into account the weight of the critical characteristic. The technique used to combine these values is up the analyst. In this example a weighted sum is used. These are then combined to provide the overall "system measure".

Table 1, 2 and 3 provide examples of populated tables representing the base system, the introduction of the new technology, and the introduction of infrastructure, procedures and staffing to accommodate the new technology. In these tables E1[4] represents the measure of the structure enabler reflecting the transfer and access of the information elements. While E2 represents the mechanism enabler and provides a measure of the interpretation and manipulation of the information elements. For the example presented in this paper, this relates to the system's ability to fuse, filter and interpret the information. It is these elements which change between system instantiations. Weightings associated with the system functions ("function weight"[5]) and the information characteristics ('weight"[6]) which are used in this example do not change between system instantiations.

The first instantiation, represented in Table 1, is the base line system which the other two instantiations will be compared against. For the second instantiation, the introduction of the proposed changes in the system can be described as follows. There is a substantial change in the transfer of external information into and out of the headquarters. This increase in information transfer is accompanied by an increase in communications bandwidth usage. It is the result of the introduction of the global positioning systems to the lower level units. These units now transmit there position automatically to the headquarters every 10 minutes instead of every 2 hours as was done in the first instantiation. The ability to access this information is hampered because procedures are not in place to accommodate such a large volume of information. The fusion of this information has also not been addressed in this instantiation. Once the information is internal to the headquarters, its transfer is also hindered due to the increased volume.

The impact of these changes on the headquarters operation is reflected in values of the dynamic aspects of the system represented by the system enablers in bold in Table 2. In considering the structure enabler, identified in the table as "E1" for each of the different functions, values of the systems ability to transfer and access information is considered. In summary the central difference between the first instantiation and the later two instantiations is seen in the planning and assessment functions in their ability to transfer and access the information elements internal

[3] In more extensive studies it is suggested that the use of methods such as modeling and simulation ([Bowden and Pearce, 2000] and [Seymour *et al.*, 2000]) and observation techniques ([Rees and Kemp, 2000] and [Mills and Stothard, 2000]) should be used to populate the tables.
[4] Each enabler takes a value of zero and one.
[5] Each function weight ("function weight") takes a value of zero and one.
[6] Each Information characteristic weight ("weight") takes a value of zero and one.

to the headquarters. For the execution function it is the ability to access and transfer information external to the headquarters.

- For the planning function the headquarters does not have the capabilities in place to handle the extra volume of information. Hence the headquarters ability to transfer and access this information is reduced. This is reflected as a reduction in the enabler value representing transfer and access for own location ("E1"). The ability to access enemy location is largely unaffected. The ability to transfer this type of information has been marginally hindered due to the impact of large volumes of information to be transferred.
- For the assessment function it is assumed that the headquarters does not have the capabilities in place to handle the extra volume of information coming in. Hence the headquarters ability to transfer and access own location information has been reduced. This is reflected as a reduction in the enabler value ("E1") representing the transfer and access for own location information. The headquarters ability to assess the enemy location is increased, as if own force locations are known more accurately, then the enemy is either in the same location and its position is known or the enemy is elsewhere. This increased situation awareness does not lead to greater amounts of information within the headquarters so the amount of information being transferred is not increased, while there is an increase in the amount of enemy location information available.
- For the execution function the headquarters has increased the communications capability to accommodate the larger volume of information. Hence the ability to transfer and access this information is increased. But the ability to access own location information once it gets to the headquarters is still a problem. The effect on own location is considered to be marginally reduced. The effect on enemy location is considered to be unchanged.

In considering the mechanism enabler, identified in Table 2 as "E2" for each of the different functions, estimates of the systems ability to fuse, filter and interpret information within the headquarters is considered.

The mechanism enabler relates to the systems ability to, manipulate and interpret own location information. The internal headquarters processes are hampered by the 10 minute manual own location updates. This difficulty arises from the larger volume of information now entering the headquarters. Fusion of the information by the headquarters staff is done manually, which is cumbersome and cannot keep up with the increased flow of information. Staff become preoccupied with the increased amount of information so they are barely able to collate the information. No value adding occurs within the headquarters functions. This increased work load means that all functions being undertaken within the headquarters are adversely affected. In particular the headquarters ability to manipulate the information degrades. This is reflected in the "E2" values identified in bold in Table 2.

- For the planning and assessment functions, the large volumes of information remain a problem in terms of manipulation and interpretation of own location data. For the enemy location, its interpretation and manipulation are slightly hindered due to the fact that effort is now being taken away to be used to collate other information in the headquarters.
- For the execution function, the increase in information volume on own location means that the headquarters ability to manipulate this information is reduced. The flow of the enemy

location information is unchanged so the values relating to this critical characteristic are unchanged.

Table 2 Evaluation for the Second Instantiation

	FUNCTIONS											
	Planning				Assessment				Execute			
Function Weight	0.2				0.6				1			
Information Characteristics	Weight	E1	E2	Weighted Function Measure	Weight	E1	E2	Weighted Function Measure	Weight	E1	E2	Weighted Function Measure
Opposition Location	0.8	**0.4**	**0.4**	0.128	1	**0.6**	**0.4**	0.6	0.8	**0.5**	**0.5**	0.8
Opposition Status	0.5	0.5	0.5	0.1	0.6	0.5	0.5	0.36	0.7	0.5	0.5	0.7
Opposition Intent	0.7	0.5	0.5	0.14	0.7	0.5	0.5	0.42	0.7	0.5	0.5	0.7
Own Location	0.8	**0.3**	**0.3**	0.096	0.9	**0.4**	**0.3**	0.378	1	**0.4**	**0.4**	0.8
Own Status	0.6	0.5	0.5	0.12	0.6	0.5	0.5	0.36	0.4	0.5	0.5	0.4
Own Intent	0.9	0.5	0.5	0.18	0.4	0.5	0.5	0.24	0.4	0.5	0.5	0.4
Topography	0.8	0.5	0.5	0.16	0.3	0.5	0.5	0.18	0.8	0.5	0.5	0.8
Cross Characteristic Function Measure				0.9				2.5				4.6

System Measure	**8.1**

For the third instantiation, illustrated in Table 3, the introduction of the proposed changes in the system represents a large change in the transfer of external information into and out of the headquarters. This increase in the volume of information transferred is accompanied by an increase in communications bandwidth. The ability for the whole system to manage this information has been also been accommodated, via the use of an automated command support system within the headquarters with the accompanying infrastructure and procedures to facilitate the transfer, interrogation and manipulation of information elements associated with the system. For comparison purposes Table 3 provides an example of what the value of the measure of such a system. For brevity a similar description as that given for the second instantiation of the actual changes in the enabler values has not been provided.

Table 3 Evaluation for the Third Instantiation

	FUNCTIONS											
	Planning				Assessment				Execute			
Function Weight	0.2				0.6				1			
Information Characteristics	Weight	E1	E2	Weighted Function Measure	Weight	E1	E2	Weighted Function Measure	Weight	E1	E2	Weighted Function Measure
Opposition Location	0.8	**0.6**	**0.7**	0.21	1	**0.5**	**0.6**	0.66	0.8	**0.8**	**0.7**	1.20
Opposition Status	0.5	0.5	0.5	0.10	0.6	0.5	0.5	0.36	0.7	0.5	0.5	0.70
Opposition Intent	0.7	0.5	0.5	0.14	0.7	0.5	0.5	0.42	0.7	0.5	0.5	0.70
Own Location	0.8	**0.8**	**0.7**	0.24	0.9	**0.7**	**0.9**	0.86	1	**0.9**	**0.9**	1.80
Own Status	0.6	0.5	0.5	0.12	0.6	0.5	0.5	0.36	0.4	0.5	0.5	0.40
Own Intent	0.9	0.5	0.5	0.18	0.4	0.5	0.5	0.24	0.4	0.5	0.5	0.40
Topography	0.8	0.5	0.5	0.16	0.3	0.5	0.5	0.18	0.8	0.5	0.5	0.80
Cross Characteristic Function Measure				1.1				3.1				6.0

System Measure	**10.2**

Table 4 provides the overall comparison of the three system instantiations. The second column gives the system measure, that is, the measure of how "well" the given instantiation allows the system to perform its functions on the information. A larger number in this column indicates that the system instantiation is better. The third column gives an indication of the change from the base line instantiation. This analysis shows that increasing the amount of information relating to own location received by a headquarters, will only improve the overall effectiveness of the headquarters if the appropriate infrastructure, staffing, procedures and analysis of this type of information are implemented.

Table 4 Comparison of System Instantiations

Instantiation	System Measure	Change
1	8.5	-
2	8.1	Insignificant
3	10.2	Moderate

4. **Conclusions**

This document presented a method for modelling a complex system and using this model to compare different system instantiations. The system consists of three components; system critical component, system functions and system enablers. Two of these, the system critical component and system functions, define the operational outcomes expected of the system and are the same for each system instantiation. The third, the system enablers, provide the capability of the system to support these outcomes. The three groups are mutually reliant and cannot be implemented independently. Once this breakdown has occurred then a system measure can be determined and different system instantiations can be compared.

A military command and control system was used as an example for the application of the method. Generic characteristics associated with the information and the functions used by a military headquarters, as defined by the authors, are used as the basis to represent the components of the system.

When related to the application to military operations, some unique capabilities arise from the method. These include the ability to generically define the information types and processes that drive an organisation's operations, independent of the level of command. Further to this, the method provides the mechanism on which to calculate a value associated with the criticality of the generic information used in a military organisation. This index, which is independent of scenario, can be used to provide insights into investigations of data degradation issues, which are important with the introduction of new information technologies. A measure representing each system option can be calculated and compared to rate the different system options.

The method described is being applied to studies in the area of battlefield command support systems and the introduction of the Armed Reconnaissance Helicopter ([Rees *et al.*, 2000]).

5. **Future Work**

An issue not raised in this document is the fact that many analysis methods for command and control systems are scenario dependent. Initial studies show that the system instantiation comparison method appears to be independent of scenario. Further research is still being conducted to determine if it is also independent of context. Early indications suggest that in the military arena it may be dependent on three broad contexts relating to the tempo of operations: low, medium and high tempo. In the system instantiation method these changes in context are represented by variations in the function weights.

Another issue that has not been considered in this paper is that of parameter sensitivity. However, a very rough sensitivity analysis shows that for the example presented the method is most sensitive to changes in the function weights. This is due to the functions used to combine the enabler measures. The authors acknowledge that before the method can be applied to real system analysis extensive sensitivity analysis has to be carried out. This will help to focus the data gathering activities on those parameters with greatest sensitivity.

The final area of currently planned future work is in the area of linking the outcomes with costs to allow for cost benefit trade-off analysis. This will allow the systems instantiation comparison method to be used to answer questions such as which instantiation is the most cost effect to implement.

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