How Does Human Factors Fit Within the COTS Philosophy?

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Abstract

Background: Recent projects within some Australian transport organisations have seen the implementation of Commercial Off The Shelf (COTS) products rather than custom designed technology. The benefit to transport organisations of procuring COTS products can include cost savings in through life support, demonstrated product and system reliability, and interoperability between operators, if multiple operators commission the same equipment. Within the transport industry there is little research and guidance as to how human factors should be managed in COTS technology to support the safe, effective and reliable integration of standardised technology into a pre-existing system.

Aim: The current paper aims to discuss issues associated with the integration of COTS products from a human factors perspective and lessons learned from project experience with Australian rail and marine transport operators.

Results: In response to the COTS philosophy, the influence on product design and functionality is limited compared to those for custom made products. Consequently the process to identify, assess and manage human factors issues needs to be adapted to effectively support product selection, installation, testing, and operation, as well as through life support. To optimise the product installation and reduce the need for product modification, the requirements of the user and existing system needs to be examined before selecting the COTS product, and potential issues, such as unnecessary functionality and inconsistency, with existing systems, which all need to be identified and managed early in the project. Conclusion: To help ensure successful integration of COTS products into existing systems, the process for assessing human factors issues needs to be adapted to help ensure the selection of the most appropriate COTS product. Modifications to the COTS product may reduce the benefits of adopting pre-existing technology and increase the cost of implementation and maintenance.

Background

Recent project experience with Australian transport organisations has identified an increase in the procurement and implementation of Commercial-Off-The-Shelf (COTS) products rather than custom designed technology when updating or implementing operation and control systems. The term COTS refers to pre-packaged mass produced technology including both software and hardware. The product is usually designed to be easily installed and to interoperate with similar systems.

The increasing migration away from custom designed technology towards pre-manufactured technology by Australian transport operators has raised a range of issues, challenges and questions for Human Factors Advisors as to how human factors can be best employed to capitalise on the use of pre-manufactured products, and to ensure effective support of the operability of the product, the current work system and the end user. In supporting these transport projects and conducting the human factors support, it has been identified that there is limited research and guidance around the implementation of COTS products and the integration of human factors to support these systems. As industry turns increasingly towards the procurement of COTS products, this is an issue that has been identified as important and that needs to be addressed to ensure the progression of efficient and safe human and system interaction.

The procurement and implementation of COTS products is identified in many industries as being a cost effective solution to many requirements for updating work systems in what can often be a costly exercise. The use of COTS products has been associated with a range of benefits, including demonstrated product and system reliability, interoperability between operators, reduced maintenance, and reduced costs of technical through life support. These factors offer a great advantage to many transport operators and organisations in supporting their ability to react to newly identified needs for system expansion while also being able to manage requirements in a cost efficient way to help maintain their competitive place within the market. However, in adopting pre-manufactured technology there are a number of benefits and limitations associated with the implementation of a standardised and mass produced product that organisations need to manage to ensure those benefits associated with the COTS product can be optimised.

Aim

The aim of this paper is to introduce a discussion to consider how human factors fits within the COTS philosophy. This paper will raise issues and questions around the scope of
Results

Current environment

The Defence industry has led much of the research into the integration of COTS products from a Human Factors perspective, recognising a need to employ pre-existing standardised technology due to factors concerning cost efficiency and system reliability. In supporting this movement, much research has been funded into the assessment of COTS products and the impact on Human Factors Integration (HFI). Bruseburg’s [1,2] report, provides a review of current literature around the integration and management of COTS products and delivers a checklist tool to support the broad assessment of COTS equipment and the decision making process for HFI. A number of reports, including Bruseburg’s [1,2], highlight the requirement for modified methods of human factors support and HFI to effectively assess the suitability of COTS products against the purchasing company’s requirements. This previous research highlights that the COTS philosophy removes the project focus from the initial design and ongoing assessment of user requirements, and instead concentrates on the need to ensure the initial assessment and selection of the correct product, along with the early identification of any product limitations or conflicts with project requirements.

With the introduction of any custom designed product, it would be expected that the organisation would review the system requirements, required product functionality and usability, the expected impact on operator roles and responsibilities, user performance and risk of error, workload, and skill set and competency requirements. It would be expected that data collection and assessment methods, such as task and workload analysis, human error analysis and review of workstation layout may be employed to ensure the organisation and product or system designer is able to capture the required detail of information to develop sufficient understanding of the requirements and limitations of the proposed product, the system, and the user. With the introduction of a COTS product though, these data collection activities may become redundant as the project’s ability to provide a solution that is a suitable match to the identified requirements becomes restricted. It is recognised that due to the standardised nature of the product and the limitation on customisation to fit the current system and user requirements, procurement projects associated with COTS technology are not able to be as flexible and reactive, and must instead recognise the limits on design variations and stakeholder influence after the product has been purchased.

Benefits of using COTS products

The use of standardised technology offers transport operators a range of benefits and assurances that make tailored product solutions appear a costly commitment when compared against the expected product output and benefits. In comparison, the COTS philosophy offers the organisation a range of benefits that add to the operator’s ability to limit spending and remain competitive in the market. The benefit to transport organisations of procuring COTS products can include cost savings, demonstrated product and system reliability, interoperability between operators, and guaranteed through life support, when compared against equivalent custom designed products.

The main advantage of adopting COTS products is related to the concept of ‘economies of scale’ i.e. the average unit cost will fall as manufacturing expands and the scale of output increases. The cost savings resulting from the increased manufacturing associated with COTS products will flow onto the purchasing company, and as a result a transport organisation can expect to make significant cost savings in the:

- **Procurement of the product,** as the initial product price can be significantly less than equivalent custom developed technology.

- **Overall system design and development,** as the manufacturer will have a specialised manufacturing processes for producing the product in bulk. The purchasing organisation will also benefit from the manufacturers learning process, as manufacturing methods can be refined to become more time and cost efficient through improved manufacturing techniques, updated technologies and test processes [3] and lessons learned from previous product models and the competitive market.

- **Possible elimination of prototype development and testing** [3], as the manufacturer may have evidence of the products functionality, operability and reliability.

- **Product lifecycle and ongoing system upgrade and maintenance,** as the manufacturer will be able to offer standardised system upgrades and maintenance tools and techniques. This last point offers a significant advantage to the purchasing company, especially if a motivation for the adoption of the product is to increase their competitive position within the market. It has been identified that the true cost for a company associated with purchasing a new product, is not associated with the initial purchase cost, but rather the maintenance of the product. Ambler et al. [3] highlights that the cost of product maintenance is close to 60% or 70% of the total through lifecycle cost. Taking these figures into account, the benefit of cost reduction, in terms of reduced cost for ongoing system maintenance and upgrades, provides a strong incentive for transport organisations to turn to the use of COTS products.
Other than offering efficient cost expenditure, the benefits of introducing a pre-manufactured product may also include:

- **Through life support and obsolescence management from the product manufacturer,** as the purchasing company’s requirements are likely to fit in with numerous client organisations and the typical work program for the manufacturing or maintenance party.

- **Demonstrated product and system reliability,** the manufacturer may be able to demonstrate documented evidence of the product and system performance and lifecycle. Previous testing may also include testing of the products usability and compliance with human factors best practice guidance.

- **Interoperability with other products,** the adoption of common and standardised equipment for such purposes as operation and control, navigation and communication can allow separate transport operators to communicate with each other and share data, and can reduce the requirement for each operator to have multiple pieces of technology in commission.

- **Development and implementation times,** the limited requirement for product development or variation can help to ensure the manufacturing company is able to provide and install the equipment on a smaller and more immediate time scale when compared to design and development projects.

**Limitations of using COTS products**

While the introduction and reliance on standardised equipment provides a range of potential benefits, there are a number of trade-offs, which largely relate to the scope available for the purchasing organisation to influence the design of the product and its interaction with the existing system it is to be integrated with. COTS products are standardised, pre-packaged, and mass produced and there will usually be limited influence the purchaser can have over the product they are buying. Significant issues and restrictions stem from the limitation on product design variation, including the design and development of the human machine interface, product functionality and capability.

The main issues that transport operators will need to manage include:

- Unwanted or additional functionality in the system or human machine interface.
- Inconsistency between the products functionality and operability and that of the existing systems or operating procedures.
- Conflicting and competing requirements between various project stakeholder groups, including the end user, the project procurement and management team, any user groups that may interface with the system, and the transport organisation.
- Limited understanding of the product and project parameters by project stakeholders.
- Possible resistance to change by the end users and project stakeholder groups. This may be a key issue in that workers’ attitudes and task characteristics can effect work performance [4].

All of the issues listed above can cause significant problems for project management, if they are not effectively identified and managed. The issues may lead to delayed project schedules, extended implementation time, increased costs, and possible increased risk of user error and potential incidents. While custom design projects will encompass the flexible scope to react to changing project requirements and issues as they arise, projects integrating COTS products will be much less reactive and require the sufficient identification, assessment and management of potential issues in the initial stages of the project.

Any change to the product design can create additional costs that are outside the initial project scope, as the product is no longer standard. The introduction and mismanagement of changes to COTS products as a result of incorrect product selection may increase project costs, due to additional manufacturing requirements, additional product and system testing, modified product maintenance and custom through life technical support, and extended training of users. Product modifications may also reduce the benefits of interoperability between operators, demonstrated system reliability, and compliance with industry standards.

With the introduction of any technology, it would be expected that the organisation would review the product’s functionality, capability, technical requirement, and its interface and usability. For projects related to the introduction of COTS products, the focus for this assessment is shifted to the initial project planning, including the development of the project scope and contract. As the capacity to modify the product will be limited after it is purchased, it is important the operator accurately assesses the requirement and expectations for the product before it is purchased [1] and further identifies ways to optimise stakeholder involvement in the initial project planning stages to increase the opportunity for stakeholder and end user buy in. If the users are not involved in the development process, they may not identify with the product which can lead to increased resistance from the user [5].

**Lessons learned and issues raised from project experience with Australian transport operators**

In response to the COTS philosophy, it is identified that the influence on product design and functionality is limited compared to those for custom made products. Consequently, the process to identify, assess and manage human factors issues needs to be adapted from those employed to manage the design and development of custom made and modified products. To effectively support product integration Bruseburg’s [1] guidance report suggests the focus for the purchasing company should be on the assessment of the initial product selection. It is recognised that to optimise the product installation and reduce the need for product modification, the requirements of the user and existing system need to be examined, before selecting the COTS product, and that any potential issues, such as unwanted or inconsistent functionality with existing systems, need to be identified and managed early.

[ 3 ]
In supporting the use of human factors integration within procurement projects, the limitation of influence on the design of the COTS product requires a varied response and approach from human factors professionals. The work is no longer around influencing the product design to ensure it meets the requirement of the user, the system, and the organisation. Rather organisations may need to work to ensure the correct product is purchased and to manage any requirements of the user, project management, and the manufacturer upfront, along with any product issues of high significance. This will help to ensure the product meets the requirements for its implementation that any issues of high significance can be identified and managed, and that project stakeholder groups can be made sufficiently aware of the project requirements and restrictions.

To identify and select a suitable product the operating company will need to accurately assess their requirements, this may involve a review of the following issues:

- The required product functionality and the requirement for improvement for the current system.
- Context of use for the product within the existing system.
- Current procedures and processes related to the system the product is to be integrated into.
- The requirements and requests of various stakeholder groups including, the end users, users who will interface with the system, project managers and the organisation.
- Operability of the product.
- Limitations of the product in comparison to required usability and functionality.
- Un-required or conflicting functionality.
- End user training and skills to ensure the risk of user error can be mitigated against. It should be considered though that while user training is advocated as a measure to support the effective integrations of the products, a reliance on the user to learn the system and react with the required behaviour sequence is not a reliable method to manage possible risks.

All of these issues may need to be accurately considered and assessed before the product is purchased to assess the complete impact and suitability of the product. While it is recognised that workers are able to adapt to work system designs, inefficient work equipment and designs can increase the risk of reduced performance and the occurrence of errors [6].

From project experience and review of current guidance documentation, it is recommended that a key to successful integration of COTS products lies with the selection of the most suitable product for the needs of the user and the system, however it should be recognised that any product is unlikely to be a perfect match for the operators requirements. While the operator’s system requirements may be specific, a COTS product is likely to be designed for broad use, so that it may be adapted to meet various system requirements, and there may be mismatches between the product and system functionality and requirements. Mohamed et al. [2] argues that even when the COTS product with the highest fit with the current system requirements is selected, the product will still have ‘many mismatches’ with the system requirements.

Although it is understood that the focus of the product integration lies with the correct product selection, and that we must identify project, product and system parameters early, it does still raise questions around how to best respond to this need.

- How do we best assess the requirements of the user and the existing system, before selecting the COTS product?
- The implementation of any custom designed product would require the assessment of such aspects as the human machine interface, task requirements, product operability and usability, work station layout and worker requirements, how can these elements be effectively measured and assessed in the initial stages of procurement projects?
- What tools and practices should be implemented to gain an accurate understanding of the user’s requirements and the behaviour of the product when it is integrated with the existing system?
- When working a standardised product, how do we plan to help ensure the system is capable of responding to possible future requirements?

These questions demonstrate the need for further research and guidance around human factors support to the integration of COTS technology.

**Conclusion**

To successfully integrate pre-manufactured technical solutions into existing systems to support a safe, efficient and reliable work system, the COTS philosophy requires the assessment and management of human factors issues to help ensure the selection of the most appropriate product, as well as the optimum configuration, installation and use of that product within the existing system. Any modifications to the standard product may reduce the benefits of adopting proven pre-manufactured technology and may increase the cost of implementation and maintenance.

The philosophy of the COTS product is to buy a mass produced commercial product and to install the product ‘as is’ to ensure lower costs, and demonstrated reliability. In procuring a COTS product the opportunity to tailor the product is limited and the addition of manufacturing requirements outside of the original product specification can increase costs and reduce the system reliability. These limitations on design variation need to be managed from the start of the project management stages, as the use of pre-designed products, rather than a customised design, means the project cannot be reactive to the requests of the user and system owners without reducing the benefits of originally procuring the standardised technology.

As the focus changes within the transport industry from custom designed technology that can be tailored for the purchasing organisation and the system it will be operated within, to pre-manufactured solutions, transport organisations and human factors professionals need to consider how to best support the COTS selection and integration process to ensure it is effective and able to support the end user and to help build
the platform for a safe, efficient, and reliable system. Being a part of a number of projects related to the human factors management of the integration of COTS products, it has become apparent that further guidance or research on the effective integration of COTS technology into a pre-existing system is required. Like any form of HFI or system design, the organisation does need to take account of the usability and human interface of the product in the context of the full work system. However, unlike with the introduction of custom made technology, there is limited influence the organisation can have on the product design after it has been purchased. Questions remain open for further research and thought as to how human factors support can best be applied to ensure accurate understanding of the needs of the users, project stakeholders, system, and the organisation to ensure the correct product is selected and any issues or restricting limitations are sufficiently identified and managed.

References


