Designing a Supply Chain Visibility Information System for the Manufacturing Industry

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***Abstract*— This paper evaluates the design and success of an Information System developed in a just-in-time UK manufacturer to combat the lack of visibility and financial impact caused by supply chain disruptions related to extreme weather and traffic events. An information system design is first presented through the use of leading academic models, with a subsequent evaluation of perceived success via 4 employee interviews within the UK manufacturer. The DeLone and McLean model Multi-Perspective Evaluation model is then used to present the interviewees responses. This paper finds the newly introduced IS to be a partial success in meeting project objectives via the reduction of incident response time by 30 minutes per incident, and the centralization of key data points. This paper contributes to literature through the provision of framework and learnings for other organizations to build and act upon, in the aims of reducing their own supply chain disruption due to extreme weather and traffic events.**

***Keywords*— Information systems, Information systems implementation, Information systems design, Manufacturing, Supply chain**

I. Introduction

Just-in-time (JIT) manufacturing is an organizational improvement philosophy aimed at increasing efficiency in the production process [1] and reducing product queue lengths and costs by storing only the required inventory for that moment in time [2]. Suppliers can be a huge risk area in JIT manufacturing, accounting for an estimated 80% of a product's lead-time [3]. This paper focuses on two specific risk areas to JIT manufacturing: unpredicted weather and traffic disruption that delay part deliveries to a manufacturing plant. There is a growing concern with the risks caused by extreme weather, as it is unpredictable and difficult to monitor [4]. Furthermore, Liyung et al. [5] claim that such events may result in economic losses. Frentzel [6] advises that companies prepare a contingency plan to manage these risk areas. He proposes that foresight is possible through Information Systems (IS) that can analyze real-life supply chain incidents.

This paper evaluates the design of an Event Monitoring Information System (EMS) developed within a UK-based manufacturing plant to counteract the aforementioned issues. The UK manufacturing plant discussed in this paper has a key focus of maintaining consistent production line flow due to its JIT operating model. This is dependent upon a global supply chain connected by a vast number of shipping ports and road networks, through which parts are received each week. The Inbound Logistics (IL) team are responsible for the receipt, storage and distribution of these parts. Prior to EMS, no previous knowledge of delays caused by traffic or weather incidents resulted in the manufacturer incurring high costs to arrange emergency transport or airfreight of alternative parts. To counteract these issues, the EMS system was developed to provide visibility of traffic and weather incidents in the supply chain. The data presented in this paper stem from the author's experience overseeing this implementation.

II. Literature Review

A. System Design Overview

The following section details the processes and technical components of the EMS system. At an organizational level, EMS could be described as a Decision Support System (DSS). Heeks [7] states that a DSS can "provide those faced with a semi-structured and unstructured decision situation with an environment that includes performance information tools to analyses the information and an easy-to-use graphical interface". The EMS system enables users to analyze masses of information on a clear interface to aid them in making an un-structured decision. EMS uses information from external sources to address rapidly changing problems, both of which are described as traits of a DSS by Laudon and Laudon [8].

The CIPSODA model [7], Figure 1, can be used to first describe the process of the EMS system. Firstly, the user accesses an administration page on the system, and using a Google Map Application Programming Interface (API), they select the exact location of relevance (e.g. a port or road network). The system then captures the latitude and longitude for this location, and the user assigns it a specific name. The location's name, latitude and longitude are then stored in a database.

Next, the user navigates to an interactive map that displays data for a location. EMS then processes the location by communicating with two external APIs, a traffic data supplier (hereby referred to as Supplier A) and a weather data supplier (hereby referred to as Supplier B). EMS sends the latitude and longitude of the location to both suppliers through the APIs. The suppliers then send all of the weather and traffic data for those co-ordinates back to EMS.

All incidents around the chosen location are displayed on the map, each incident with its own marker. The user can then filter by incident severity. Once a filter is applied, EMS follows the same processing steps to retrieve the data through the APIs. Following this, the user decides whether any incident could result in delivery delays to the

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manufacturer. If the incident is likely to result in a delay, the user will firstly investigate the possibility of changing routes with the haulier in transit. If a port is closed, the user tries to arrange for parts to be delivered from an alternative port. If the aforementioned options are impossible, the user orders the same parts from a supplier who is able to deliver through an alternative route, or in an extreme scenario they arrange emergency airfreight.

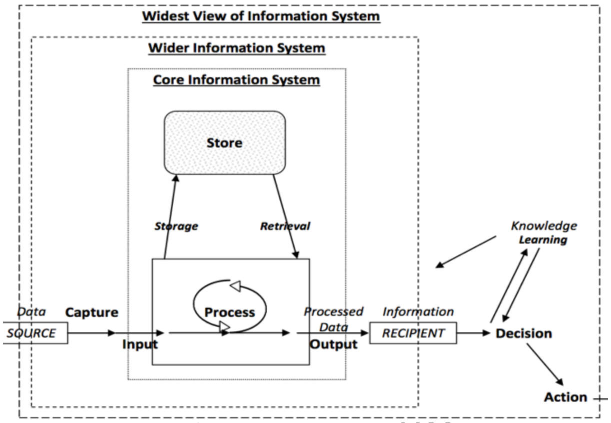

Figure 1. CIPSODA Model [7]

The hardware used by the EMS is standard and lightweight; EMS mostly harnesses data from external suppliers. A full representation is categorised in Figure 2, through the use of Heeks' [7] CIPSO model.

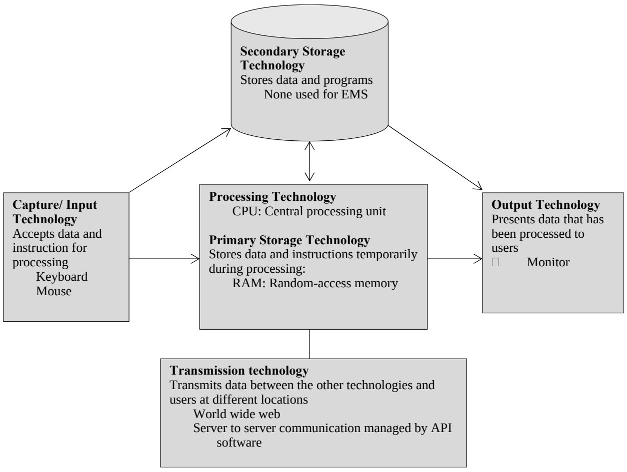

Figure 2. Categorizing EMS Hardware Using CIPSO [7]

B. Organizational Function

To understand how EMS supports the manufacturer's IL team and the wider organization, it must first be understood how the organization is impacted by weather and traffic incidents.

McKinnon [9] found that traffic congestion results in the delays of part deliveries to warehouses, and thus compromises their operating efficiency. A revisited study by McKinnon et al. [10] found that traffic congestion is responsible for 23% of the total delay time in road freight transport within the UK. This is a major issue for manufacturers as unmonitored traffic congestion could result in major stock shortages and potential line stoppages. Whilst this research only includes UK statistics, an assumption could be made that any supply chain could suffer from traffic congestion. On the other hand, Cassidy's [11] study revealed that extreme weather has the ability to cause delays in the supply chain by shutting down traffic routes and shipping ports. Thus, such unexpected events create numerous logistical challenges in a JIT operating method, and the IL team need to be reactive in their response to the closures of traffic routes or shipping ports on a daily basis. The inability to respond in a timely manner can result in part shortages, line stoppages and significant financial losses. Cassidy also noted that companies providing emergency transportation services could make a large profit from extreme weather incidents; another example of where EMS aims to reduce such costs for the UK manufacturer.

The Step Model [7], Figure 3, can be used to emphasize how EMS supports organizational decisions to combat such extreme weather events. The first stage in the Step Model is intelligence gathering. A problem is detected, highlighting a deviance between the actual situation and the desired outcome [7]. EMS highlights delays in the supply chain caused by weather or traffic incidents. The true problem is that these delays could result in reduced stock in the manufacturer warehouses, increasing the risk of line stoppages.

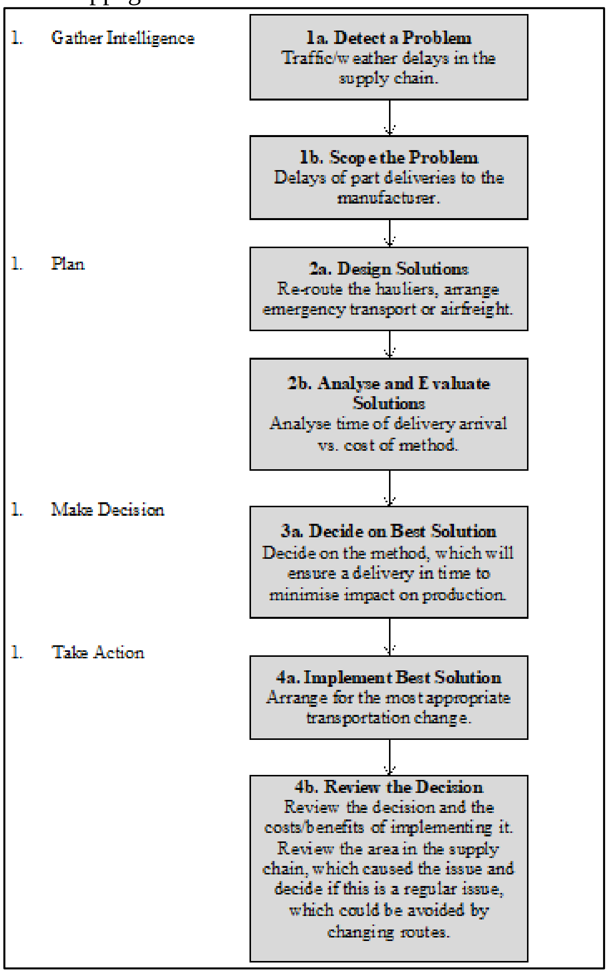

Figure 3. EMS Step Model [7]

In the planning stage, the IL team use EMS to check the traffic and weather conditions at alternative ports or road networks. They then assess whether it is possible to re-route the hauliers and still receive the parts in the required timeframe. If no alternative route exists for the hauliers already in transit, the IL team investigate the possibility of arranging emergency transport locally or from a location with no disruptions. In extreme scenarios, the team will decide to deliver parts by airfreight. Although the latter two choices can incur high costs, they may be a cheaper option than stopping production flow. The IL team assess each option and analyze the time of delivery arrival versus the cost of that option.

In the decision-making stage, the team uses the information output from the previous stage to decide on a solution that minimizes the impact on production, while favoring the cheapest option available to achieve this. Although quantitative costs are considered, the decision taken leans towards Heeks' [7] hybrid behavioral decision-making methodology, whereby the decision is made on judgement, based on past experiences of similar delays. A decentralized approach [7] to decision making is usually applied, whereby the individual user who notices the problem makes the decision. This is due to each member of staff looking after their own 'scheme' (specific supply chain area using a particular group of suppliers).

In the action stage, the team arranges for the most suitable transportation change based on the decision made in the previous stage. To prepare for similar situations in the future, the decision is reviewed by analyzing the costs versus benefits. The team also review the supply chain area that caused the delay and investigate previous incidents to understand if there are any recurrent delays. If this is the case, the team try to minimize use of this particular port or road network, thus learning from the system.

III. Method

To evaluate the success of the EMS system, semi-structured interviews were conducted with 4 members of the team. The semi-structured interviews were designed to evaluate IS success through the use of the DeLone and McLean [12] Multi-Perspective Evaluation model. This model presents 6 key factors to IS success, and thus was deemed appropriate for use in this study.

IV. Results

The two main objectives of EMS were to provide visibility of weather and traffic incidents and to reduce emergency transport and airfreight costs. The DeLone and McLean [12] model (Figure 4) is used to reference back to the interview responses and evaluate whether the EMS system has met its objectives, and thus determine perceived success or failure.

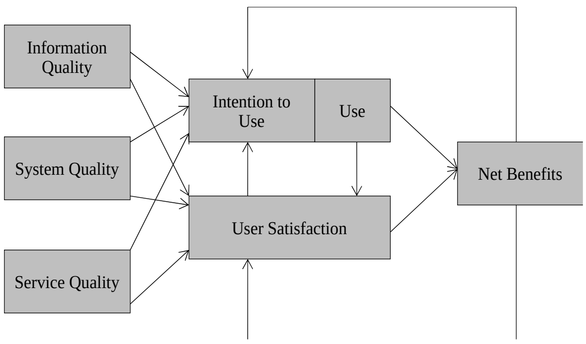

Figure 4. EMS Step Model [7]

A. *Information Quality*

Feedback from user interviews highlighted that Supplier B does not frequently update their data, meaning that on 5 pilot runs the EMS downloaded expired weather data for several ports and traffic routes. The traffic data, on the other hand, was perceived to be 100% accurate with the users advising that the data updates in real-time and allows them to respond swiftly to traffic incidents. Interviewees also expressed that the traffic information is of a high standard and has been a great contribution to their role as it was not previously possible to visualize such a vast landscape of traffic incidents in real-time.

B. *System Quality*

Boddy et al. [13] advised that accuracy and response time are two factors that should be analyzed when determining the success of an IS. User interviews highlighted that the perceived system quality of EMS can vary on a daily basis. For example, for example, 2 of the pilot runs highlighted an issue with the data traffic or server capacity with regards to Supplier B. It was noted by interviewees that a high number of weather incidents caused the system's response time to increase by around 30 seconds. The interviewees stressed that this adds difficulty to respond to incidents in real-time and can have a negative impact on the users' ability to make an informed decision. Contrastingly, the interviewees reported that the traffic data downloaded instantaneously on all pilot runs, and the response time has been consistent since implementation.

C. *Service Quality*

Pitt et al. [14] believed that measuring service quality was vital when evaluating the success of an IS. At the time of system development, EMS was programmed in the most up-to-date software standards as governed by manufacturer's frameworks. Since then, the reliability and responsiveness of the system has been questioned by numerous users due to the issues experienced with the weather data.

D. *Use and User Satisfaction*

From a use and user satisfaction perspective, EMS could be seen as a clear success. The system been incorporated as a standard business process. Results from interviews highlighted that the majority of team members embraced the new technology and, in general, find it easy to use. However, a longer-serving team member indicated resentment to using the system because it was previously one employee's role to collate all of the information from external websites and provide this to the rest of the team. The same user did, however, state that the information gathered from the system makes it easier for them to respond to and manage incidents, with the exception of the inaccurate weather data.

E. *Net Benefit*

Interviewee feedback highlighted that the weather data was inaccurate approximately 35-50% of the time during pilot runs, with the traffic data stated to be 100% accurate. This demonstrates a partial fulfilment of the objective to provide visibility of weather and traffic incidents in the supply chain.

The interviewees reported that EMS has provided data that was previously difficult to locate, and relied on them scanning various websites as an incident occurred. The interviewees estimate the EMS has thus reduced their overall decision-making time by a window of 30 minutes per incident, due to the centralization of data. The interviewees have also learned from the system by adding contingency time with supplier deliveries, or avoiding a location that is subject to recurrent delays.

Project benefit sheets have highlighted that EMS has reduced emergency transport and airfreight costs, thus fully meeting the objective to reduce costs, though as it is still early in its implementation and so the exact net benefit could change.

Although there are clear issues relating to the weather data, EMS still partially meets the objective of a visible landscape, and since it has also resulted in cost reduction, EMS could be labelled as a partial success.

F. Explanation of EMS' Partial Success

This section explains the reasons for EMS's partial success, as well as the elements of the IS that failed, in some capacity, to prevent EMS from being a full success. The Onion Ring Model [7], Figure 5, helps to explain the perceived successes or failures.

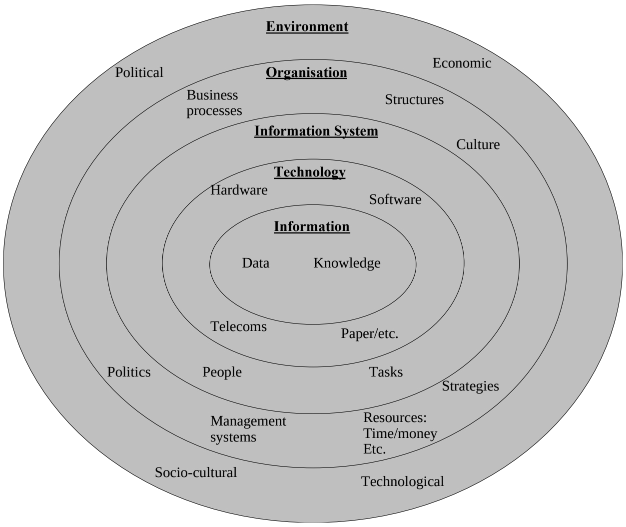

Figure 5. Onion Ring Model [7]

Saunders and Daigle [15] proposed that a consistent view of clean, reliable data allows users to spend more time assessing the impact of unexpected change. In the information layer, the traffic data retrieved aligns with Heeks' explanation of the CARTA Model [7]. The data is complete, accurate and relevant in terms of traffic incidents; timeliness in regard to instantaneous response and the mass amount of data is presented clearly. The weather data is not complete as it often omits data for gust speeds around ports. As identified in Section 4.5, the timeliness of the data download often fluctuates.

As data is provided from external suppliers, it is difficult to evaluate the technology layer without doing a full supplier technological analysis. The issue of slow response times relates only to the weather data. Thus, an assumption could be made that there is a network issue somewhere in Supplier B's technology.

One of the initial issues with EMS was the resistance to change from a longer-serving team member. For an IS to be successful, it requires support from management to invest in the IT skills of its employees [16]. The resistant team member was used to text based, legacy systems with limited experience of using web-based systems.

In the organization layer, the system is a success as decision-making time has been reduced and the key objective of cost reduction has been achieved. However, the strategy for testing was not successful, as the issues with the weather data were not noticed until after implementation in the pilot runs.

The system success is impacted, to some extent, by environmental factors. The higher the number of incidents occurring at a particular time, the more frequent the system will be used. Consequently, the issue with the response time to weather data is linked to an external factor that the manufacturer has no method of controlling. An assumption could be made that external technological forces might affect the system. The reason for missing gust speeds or weather temperatures at certain locations could be due to Supplier B not having the relevant technology to measure these factors. This is an assumption and cannot be factually concluded without a full analysis of the supplier's data gathering methods.

V. CONCLUSION

EMS has been identified as a partial success. Whilst the weather data has been noted as sometimes being inaccurate, the system has still delivered enough valuable information to enable users to make instant decisions that have reduced the need for expensive emergency transport and airfreight. These costs have been reduced, meeting senior stakeholder objectives.

The main issues identified with EMS are inaccurate data and some change resistance from longer-serving team members. In hindsight, the test plan was not thorough enough to identify these issues, and thus recommendations for any future projects with an EMS are to explore other several data suppliers, conduct more thorough analysis of their technology and create a robust test plan. Another recommendation would be to involve the team in the design process and to be transparent about the benefits this will bring to their job role and the company itself.

In conclusion, this implementation paves the way for similar implementations in other manufacturing organizations which rely on complex supply chains, and the learnings of this EMS project can help influence successful future implementations.

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