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DECISION SUPPORT SYSTEM IN SUPPLY CHAIN MANAGEMENT: LITERATURE REVIEW

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ABSTRACT: *The term Decision Support System (DSS) is widely, though inconsistently used, but in its essence, it stands for any kind of "system" which provides valuable information necessary to support decision making (DM) process. These systems are much appreciated in highly complex environments where problems or tasks have varying degrees of structure, majority of them being unstructured or semi-structured. Nowadays, manufacturers need systems that helps to react and adapt to the constantly changing business environment. The internal data processing system of a company can only offer minimum support because it is related to transactions. Hence, DSS combine human skills with the abilities of computers to provide efficient management of data, reporting, analytics, modelling and planning issues. This paper provides the reader of a comprehensive overview of the state-of the-art literature on DSS and describes present techniques of relevant DSS applications within supply chain management.*

KEYWORDS: DSS, Systems, Supply Chain, Models,

INTRODUCTION

Decision Supports Systems (DSS) are computer-based information systems designed in such a way that help managers to select one of the many alternative solutions to a problem. It is possible to automate some of the decision-making processes in a large, computer-based DSS which is sophisticated and analyse huge amount of information fast. It helps corporate to increase market share, reduce costs, increase profitability and enhance quality. The nature of problem itself plays the main role in a process of decision making. A DSS is an interactive computer based information system with an organized collection of models, people, procedures, software, databases, telecommunication, and devices, which helps decision makers to solve unstructured or semi-structured business problems**.** When decision support is packaged as an interoperable system with interchangeable parts, it is a DSS.

Decision Support Systems: History, Terms, Characteristics

Although the field of DSS is already mature (detailed historical timeline is provided by Power, 2007), there is still an ongoing debate on the origins of DSS, DSS classification and in the end, definition of decision support system. Majority of researchers agree that DSS came along with first computers. Apparently, some of the first decision support systems came from Carnegie Institute of Technology, where researchers were conducting "theoretical studies of organisational decision making" and MIT project on "interactive computer systems" in the late 1950s and early '60s (Keen and Morton, 1978). Pioneering papers in this area were published in the mid and late '60s (e.g. Scott Morton and Stephens, 1968; Scott Morton and McCosh, 1968; Ferguson and Jones, 1969), but it seems that the first use of the term "decision support system" was in Gorry and Morton's article from 1971 (Power, 2007). Shim et al. (2002) also

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stated that the original concept of DSS was first "clearly defined by Gorry and Morton who integrated Anthony's (Anthony, 1965) categories of management activity and Simons's (Simon, 1960) description types".

A decision-support system (DSS) is a special kind of computer-aided automated tool for decision-making processes. In DSS a decision process consists of four stages: problem input, analysis, solving and output of results. Situation assessment, information fusion, and alternatives generation are the three important functions in any decision support system. One of the first definitions of decision support system came from Little (1970), when he defined decision calculus as "a model-based set of procedures for processing data and judgments to assist a manager in his decision making". He also argued that for a successful system there are some prerequisites: a system needs to be simple, robust, easy to control, adaptive and complete on important issues (conflicts with simplicity), which are desirable features of a DSS even nowadays. Also, one early definition of DSS, by Keen and Scott Morton (1978), states that DSS is about pairing the best characteristics of man and machine to improve the quality of decisions: "It is a computer-based support system for management decision makers who deal with semi structured problems". Bonczek et al. (1981) defined a DSS as a computer-based system consisting of three interacting components: a language system, a knowledge system and a problem-processing system. According to Turban and Aronson (2001) the central purpose of a DSS is supporting and improving DM process. In practice, decision support system is referred a "tool" when it is packed, and usually, installed on a computer.

A Decision Support System (DSS) is an interactive, flexible, and adaptable computer based information system that utilizes decision rules, models, and model base coupled with a comprehensive database and the decision makers own insights, leading to specific, implementable decisions in solving problems that would not be amenable to management science models. Thus, a DSS supports complex decision making and increases its effectiveness. Below are the benefits of the DSS:

1. Handle large amounts of data like database searches.
2. Obtain and process data from different sources including internal and external data stored on mainframe systems and networks.
3. Provide report and presentation flexibility to suit the decision maker's needs.
4. Have both textual and graphical orientation like charts, trend lines, tables and more. 5. Perform complex, sophisticated analysis and comparisons using advanced software packages.
6. Support optimization, satisfying, and heuristic approaches giving the decision maker a great deal of flexibility in solving simple and complex problems.
7. Perform "what-if" and goal-seeking analysis.

Moreover, according to the literature, we can say that there are six capabilities that distinguish a DSS:

1. Support for problem-solving phases including the intelligence, design, choice, implementation and monitoring

ISSN 2054-0930 (Print), ISSN 2054-0949 (Online)

2. Support for different decision frequencies that range from one-of-a-kind (i.e., merging with another company) to repetitive (i.e., how much inventory to purchase this week)
3. One-of-a-kind decisions are handled by an ad hoc DSS
4. Repetitive decisions are handled by institutional DSS
5. Support for different problem structures ranging from high structured and programmed to unstructured and non-programmed
6. Support for various decision-making levels including operational-level decisions, tactical-level decisions and strategic decisions.

Furthermore, the DSS have the following characteristics:

1. They are used to tackle ill or semi-structured spatial problems – these occur when the problem, the decision-makers objectives, or both cannot be fully and coherently specified.
2. They are designed to be easy to use; the often very sophisticated computer technology is accessed through a user-friendly front end.
3. They are designed to enable the user to make full use of all the data and models that are available, so interfacing routines and database management systems are important elements.
4. The user develops a solution procedure using the models as decision aids to generate a series of alternatives.
5. They are designed for flexibility of use and ease of adaptation to the evolving needs of the user.
6. They are developed interactively and recursively to provide a multiple pass approach which contrasts with the more traditional series approach - involving clearly defined phases through which the system progresses.

The Components of DSS

A DSS application can be composed of following subsystems:

1. **Data Management subsystem:**

The database management subsystem includes a database, which contains relevant data for the situation and is managed by software called the database management system (DBMS). The database management subsystem can be interconnected with the corporate data warehouse, a repository for corporate relevant decision-making data.

2. **Model Management subsystem:**

The model base gives decision makers access to a variety of models and assist them in decision making. The model base can include the model base management software (MBMS) that coordinates the use of models in a DSS. This component can be connected to external storage of data.

ISSN 2054-0930 (Print), ISSN 2054-0949 (Online)

3. **Knowledge-based Management subsystem:**

This subsystem can support any of the other subsystem or act as an independent component. It provides intelligence to augment the decision maker's own. It can be interconnected with the organization's knowledge repository, which is called the organizational knowledge base.

4. **User Interface subsystem:**

The user interface, also called the dialog management facility, it allows users to interact with the DSS to obtain information. The user interface requires two capabilities; the action language that tells the DSS what is required and passes the data to the DSS and the presentation language that transfers and presents the user results. The DSS generator acts as a buffer between the user and the other DSS components, interacting with the database, the model base and the user interface.

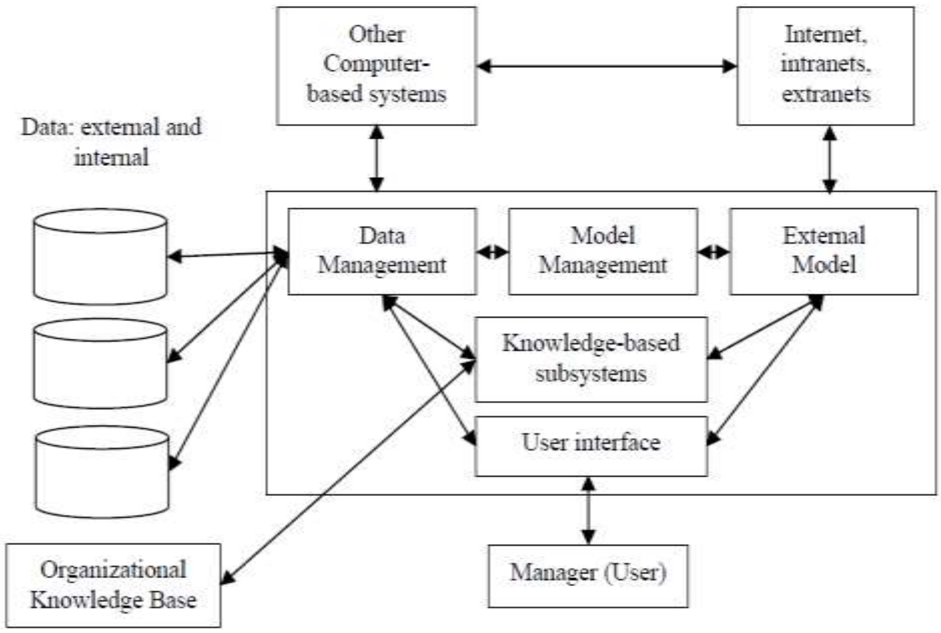

Figure 1: A Schematic View of DSS

Structure of Decision Supports Systems

According to Bozarth & Handfield (2008), the three major components of a DSS are the input databases and parameters, the analytical tools, and the presentation mechanism.

1. The input database contains the basic information needed for decision making. This can be a PC-based database extract designed for the specific problem, a data warehouse with an accumulation of a company's transactions, or distributed databases accessed through a network. This database can also include certain parameters and rules, such as the desired service level, hard-coded restrictions, and various other constraints.

2. The data analysis usually involves embedded knowledge of the problem while also allowing the user to fine-tune certain parameters. The analytical tools employed are operations research and artificial intelligence–based algorithms, cost calculators,

ISSN 2054-0930 (Print), ISSN 2054-0949 (Online)

simulation, flow analysis, and other embedded logic procedures. This component is the most complex, because there are few off-the-shelf solvers that can deal with the huge variety of problems that companies face.

3. Various database and spreadsheet presentation tools can be used to display the results of DSS analysis. Often, however, the output contains too much information, such as lists and tables, which may be difficult for the decision maker to absorb. Therefore, various data visualization techniques are employed to enable the user to comprehend the vast quantity of output data. For example, location, routing, and sales DSSs use geographic information systems (GISs) to display complex geographic data in problems such as site location, routing, and supply chain analysis. Similarly, scheduling systems use Gantt charts to display factory schedules, and simulations use animation to illustrate the relationships in the model.

Decision Making Process

Decision-making is the cognitive process of selecting one course of action from among multiple alternatives. It is said to be a psychological construct because the process of deciding is not visible. Only the result of the process can be observed in the form of a commitment to act. Decision-making is an important part of many professions, where specialists apply their expertise in a given area to making informed decisions. As defined by Baker et al. (2002), efficient decision-making involves a series of steps that require the input of information at different stages of the process, as well as a process for feedback. In business, there can be dozens, hundreds, or even millions of different courses of action available to achieve a desired result. The problem is deciding on the best alternative.

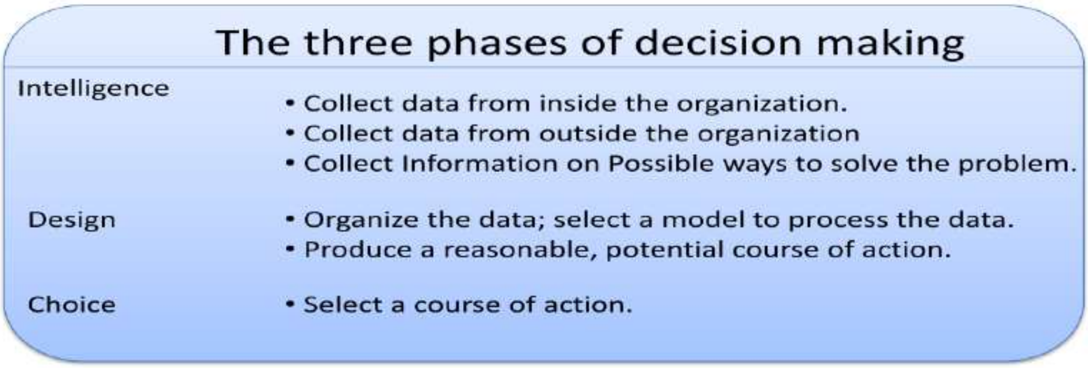

Figure 2: Decision Making process. Source: Effy (2009).

Herbert Simon, a Nobel Prize winner, also described the manager 's decision process in the same three stages. The **intelligence stage** involves searching the surrounding environment for certain conditions those are in need for deciding. The **design stage is** where to inventing, developing and analysing possible actions. The final stage is to choose from the different alternatives (Rue and Byars, 2009). Laudon and Laudon (2006) added one more step to the process. They added the **implementation step** that is responsible for testing the solution and try to make it better.

According to Dessler (2002), the manager who approached decision making rationally have to:

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1. Have complete information about the situation.

2. Perfectly define the problem.

3. Identify all the criteria and weigh all of them.

4. Know all possible alternatives and assess each one.

5. Choose the best alternative.

Thus, the rational decision-making process should include (Dessler, 2002):

1. Define the problem: Managerial decision making is sparked by identifying the problem. In addition, identifying the problem correctly is really hard.

2. Identify and weigh the criteria: Some criteria are more important than others, which leads to the fact that the managers weigh some criteria more than weighing another one.

3. Develop alternatives: To develop good and reliable alternatives is a very complex situation. This is where managers differ from each other.

4. Analyse the alternatives: This step requires forecasting the future which makes it the most difficult step in the process. The key point—the decision process should collect and analyse useful data that lead to effective actions.

Decisions Support Systems Taxonomy

Haettenschwiler (2001) differentiates between passive, active and cooperative DSS,

- Passive DSS: assists the decision making process, but cannot produce explicit decision suggestions or solutions.
- Active DSS: can produce decision suggestions or solutions.
- Cooperative DSS: allows the decision maker to interact with the system by modifying, completing, or refining the decision suggestions. system again improves, adds, and refines the suggestions of the decision maker and sends them back for validation.

One of early DSS classifications is so called Alter's taxonomy (Alter, 1980). He grouped DSS according to generic decision support operations that can be completed by such systems:

- File drawer systems – deal with data on a basic level.
- Data analysis systems – add possibility for analysis of data.
- Analysis information systems – data from databases is used to "feed" models.
- Accounting and financial model – usually used for "what-if" analysis in accounting and finance.
- Representational models – scenario analysis using simulation models.

ISSN 2054-0930 (Print), ISSN 2054-0949 (Online)

- Optimization models – given the constraints and criterion function provide optimal solution.

- Suggestion models – provide a number of alternatives and suggest actions.

Frequently cited classification is also Power's taxonomy (Power, 2002). He differentiates, on conceptual level, between:

- **Data-Driven DSS**: they emphasize access to and manipulation of large databases of structured data (especially a time-series of internal company data and sometimes external data). Simple file systems accessed by query and retrieval tools provide the most elementary level of functionality. Data-Driven DSS with Online Analytical Processing (OLAP) provide the highest level of functionality and decision support (Dhar and Stein, 1997). Executive Information Systems (EIS), Geographic Information Systems (GIS) and Business Intelligence Systems are also examples of Data-Driven DSS. The main goal of Business Intelligence and Analytic Systems is to increase the quality of the information that is available for decision making induced by the improvement of data processing Chaudhuri et al. (2011). In this case, the key requirements of a typical data-driven DSS are access to a large amount of data and, at the same time, high quality of the underlying data. The success of a DSS always depends on the access to accurate, well-structured and organized data (Power, 2008). If these requirements are not fulfilled, a data-driven DSS will not work efficiently.

- **Model-Driven DSS**: they include systems that use accounting and financial models, representational models, and optimization models. Model-Driven DSS emphasize access to and manipulation of a model. Simple statistical and analytical tools provide the most elementary level of functionality. Model-Driven DSS use data and parameters provided by decision-makers to aid them in analysing a situation, but they are not usually data intensive. The main component in the model-driven DSS architecture are one or more quantitative models. that provide the functionality. Analytic tools based on algebraic models allocate an elementary level of functionality. They are used many times in building model-driven DSS applications. Generally algebraic models are developed within spreadsheets. To develop and build more complex models for decision making, decision analysis, optimization and mathematical programming models, and simulation techniques were used. Today, various decision support models are available for different levels of the supply chain, including production planning and scheduling (Munhoz and Morabito, 2014), demand management (Seethamraju, 2014), and logistics planning (Wang et al., 2015). Model-driven DSS using simulation and rapid modelling techniques conduct multiple experiments to show the effects of alternative conditions and courses of action (keen, 1980). For decision support in the area of supply chain management several kinds of simulation methods are in common use, e.g. Monte Carlo simulation, discrete simulation, agent-based and multi-agent simulation, system dynamics, and visual simulation (Zhang, 2016).

- **Document-Driven DSS**: they integrate a variety of storage and processing technologies to provide complete document retrieval and analysis. Examples of documents that would be accessed by a Document-Based DSS are policies and procedures, product specifications, catalogues, and corporate historical documents, including minutes of meetings, corporate records, and important correspondence. Examples for decision aiding tools are search engines linked to document-driven DSS like WebCrawler or

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Alta Vista. Mostly, documents are not standardized in a uniform pattern. In this way information retrieval is used to find documents out of an unstructured form within large data collections.

- **Communications-Driven and Group DSS:** they include communication, collaboration and decision support technologies which allow groups of decision makers to work together in a coordinate way. They are sometimes identified as Group DSS (GDSS). A GDSS is a hybrid DSS that emphasizes both the use of communications and decision models. A Group Decision Support System is an interactive computer-based system intended to facilitate the solution of problems by decision-makers working together as a group.

- **Knowledge-Driven DSS**: they are person-computer systems with specialized problem-solving expertise. The "expertise" consists of knowledge about a domain, understanding of problems within that domain, and "skill" to solve some of these problems. A related concept is Data Mining. Data Mining tools can be used to create hybrid Data- Driven and Knowledge-Driven DSS.

Table 1 summarizes the DSS framework described above, identifying relationship among DSS type, user groups, purpose, and enabling technology.

Table 1. DSS Framework

DSS Type	**User groups**		**Purpose**	**Enabling technology**
	internal	**external**		
Data driven	Managers & staff	Customers & Suppliers	Query data warehouse	Mainframe, client/server
Model driven	Managers & staff	Customers & Suppliers	Scheduling, Decision analysis	Standalone Workstations
Communications driven	Internal teams	Partners	Collaborative Decisions	Client/server, Web
Knowledge driven	Internal users, specialist Groups	Partners	Strategic and tactical decision Making	Client/server, Web

Source: adapted from Power (2002)

Supply Chain Decision Support Systems

Decision-support systems for supply chain management are a fast-growing sector of the logistics software industry. DSSs will continue to evolve and to adopt standard features

and interfaces to adapt to the competitive environment and provide the flexible

solutions required in today's markets. Table 2 shows the different layers of the decision support systems in supply chain.

ISSN 2054-0930 (Print), ISSN 2054-0949 (Online)

Table 2. Types of DSS in Supply Chain

Supply Chain DSS	Definition
Logistics network design	Network design involves the determination of warehouse and factory locations and the assignment of retailers or customers to warehouses. Typical input data include candidate locations, transportation costs, aggregate demand forecasts, and so on. Heuristic or exact algorithms are used to suggest network designs. Not all criteria can be quantified, so the decision maker must ultimately use his or her judgment.
Supply Chain Master Planning.	It is process of coordinating production, distribution strategies, and storage requirements to efficiently allocate supply chain resources to maximize profit or minimize systemwide cost. Supply chain master planning allows companies to plan ahead for seasonality, promotions, and tight capacities.
Operational Planning Systems.	This layer of systems includes different types of systems, ranging from demand planning tools to tools that assist with the details of production and sourcing strategies. Unlike strategic network design and supply chain master planning systems, these systems typically provide feasible solutions but not optimized ones.
	An inventory management DSS uses transportation and holding cost information, along with transportation lead times, facility processing time, committed respond time to the upstream facilities as well as service level by product by customer. The objective of these DSSs is to use transportation and inventory holding costs, demand forecasts and forecast error, and service levels to determine the levels of inventory, in particular, safety stock levels, to keep in each location in each period.
Transportation planning	Transportation planning typically involves not only the dispatching of a company's own fleet but also decisions regarding selection of a commercial carrier on certain routes. An important component in transportation planning is fleet routing.
Production scheduling	Production scheduling DSSs propose manufacturing sequences and schedules. A production scheduling DSS can use artificial intelligence and mathematical and simulation techniques to develop schedules. Artificial intelligence–based production schedules typically involve rules that were previously used by the human schedulers who scheduled the particular processes in question. Optimization-based scheduling systems use algorithms to develop schedules that maximize or minimize some set of objectives.
Material requirements planning (MRP).	MRP systems use a product's bill of materials and component lead times to plan when manufacturing of a particular product should begin. Although these DSSs typically do not use sophisticated mathematical approaches, they are very popular in industry

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Operational execution systems.	These are real-time systems that allow executives to run their business efficiently. Of course, some of the decisions made in real time require those at the front end of the supply chain to have information and visibility to the back end of the supply chain.

Source: Adapted from Bozarth & Handfield (2008)

Important Considerations in DSS Application and Evaluation in Supply Chain Systems.

When applying a particular DSS, the following issues should be considered:

1. Applying decision support systems requires much time and effort in building and integrating databases from multiple data sources and sectors.
2. Developing a decision support system to address one issue might affect other issues which should be put into consideration during the design phase to save time and effort and avoid duplication of activities.
3. Providing decision support systems for development planning is considered urgent and critical.
4. Decision support systems design should allow for a crisis management mode of operation.
5. The effectiveness of the decision support system depends on the availability and accessibility of timely, relevant and accurate information.
6. Successful implementation of decision support systems is a necessary but not sufficient condition for successful institutionalisation of DSS.
7. Evaluation and control of decision support systems is a vital process that should accompany all phases of implementation and institutionalisation in order to provide a real-time response to changes occurring in the environment.
8. Continuous multi-level training of human resources is a critical element in the successful adoption, adaptation, and implementation of decision support system.

When evaluating a particular DSS, the following issues should be considered:

1. The scope of the problem addressed by the decision maker, including the planning horizon.
2. The data required by the decision-support system.
3. User interface capabilities.
4. Analysis requirements, including accuracy of the model, ability to quantify performance measures, desired analytic tools—that is, optimization, heuristics, simulation, and computational speed needed.
5. The system's ability to generate a variety of solutions so that the user can select the most appropriate one, typically based on issues that cannot be quantified.

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6. The presentation requirements, including issues such as user-friendliness, graphic interface, geographic abilities, tables, reports, and so on.
7. Compatibility and integration with existing systems; this includes the ability of the database interface to accept and produce standard file formats.
8. Hardware and software system requirements, including platform requirements, flexibility to changes, user interfaces, and technical support.
9. The overall price, including the basic model, customization, and long-term upgrades; note that support and customization are often far more expensive than the initial investment.
10. Complementary systems. Does the vendor have suites of products that make it easier to purchase from one source? For example, in some cases a routing DSS also includes load planning.

CONCLUSION

This paper reviewed the concept of DSS. The review of literature demonstrated that Decision Support Systems offer a variety of application possibilities including the Power (2002) classification for the DSS. The paper gave a clear understanding of the differences among these classifications. Moreover, the paper highlighted the decision-making process, components in a DSS process and types of DSS in supply chain management. The paper suggests some important points to be considered when applying the DSS systems within supply chain framework.

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