Opportunities to Transform Public Health Supply Chains in Developing Countries using Decision Support Systems

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Digital Square

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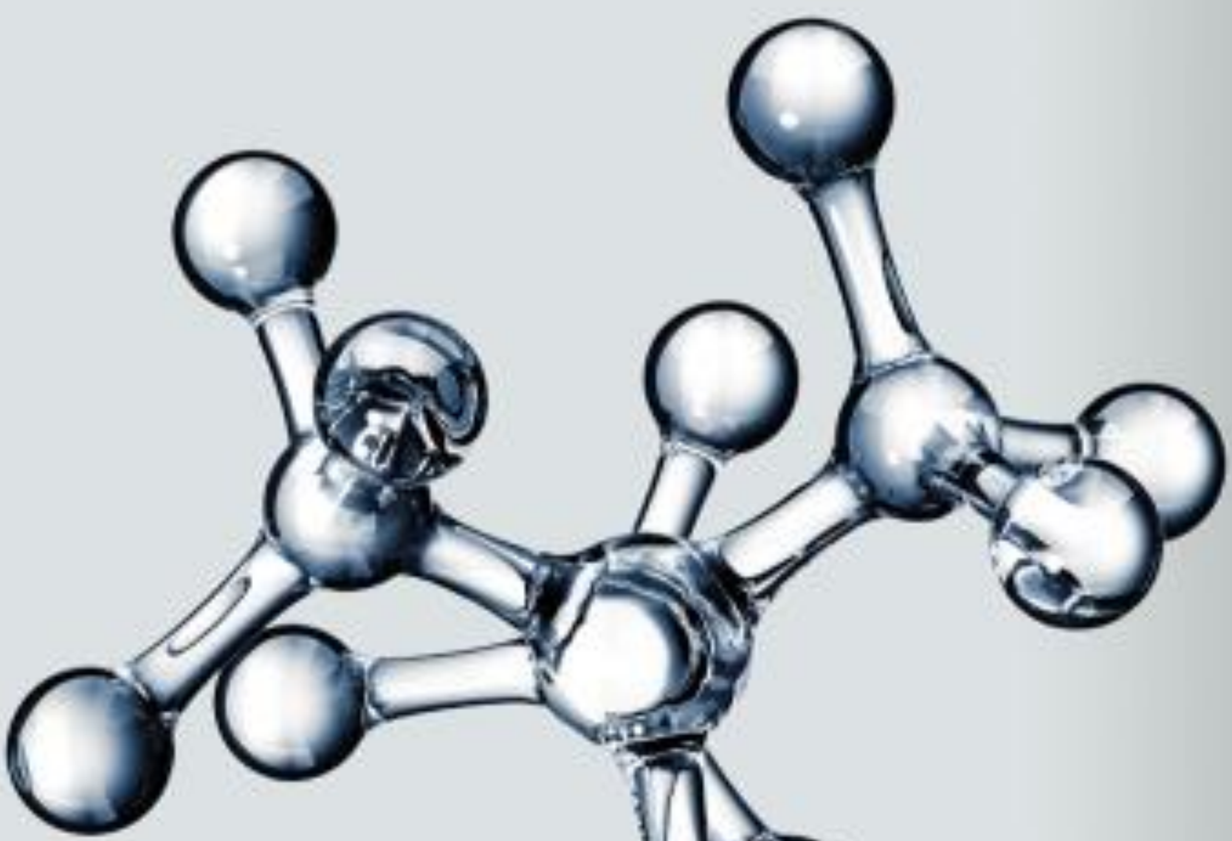


The Decade to Deliver

As we approach the fifth year of the post-2015 Sustainable Development Goals the UN reports that we are not on track to achieve them. In the words of Secretary-General António Guterres, "*we must inject a sense of urgency*"[1] in advancing these goals. The third Sustainable Development Goal on health and well-being sets out ambitious targets around dramatically reducing maternal mortality, newborn and child mortality, deaths from neglected diseases and more.

There is a critical need to strengthen public health in developing countries (PHDC) by investing strategically in innovation and technology that will improve their performance. We now have a wide range of effective and life-saving health products to help us meet these goals, but these products will not reach those who need them without a well-functioning, transparent and efficient supply chain to deliver them.

The supply chain is inherently complex, and decision-makers constantly manage the risk that medical products will not be available when and where they are needed. **Decision Support Systems (DSS) are computer-based systems or subsystems that enhance the ability to use data to identify where decisions need to be made and to assist in making them.**[2] They have the potential to reduce the burden on decision-makers and help overcome challenges in using data and analysis in decision-making.

To identify the opportunities and understand the path to DSS implementation this study engaged over 45 stakeholders for in-depth interviews and received additional input from 160+ survey respondents. In addition, the research team completed a rapid review of DSS use cases[3] in healthcare across developed and developing countries, resulting in a catalog of over 150 real-world examples.

Benefits of DSS

DSS bring substantial benefits to supply chain performance. DSS are essential for visualizing the current situation, predicting future outcomes, connecting decision-makers with data sources across the supply chain and adjusting and optimizing supply chain functions. Specifically, there are five key benefits for DSS solutions to improve supply chain performance:

1. Connect and Integrate
2. Sense and Predict
3. Observe and Describe
4. Learn and Adapt
5. Optimize and Automate

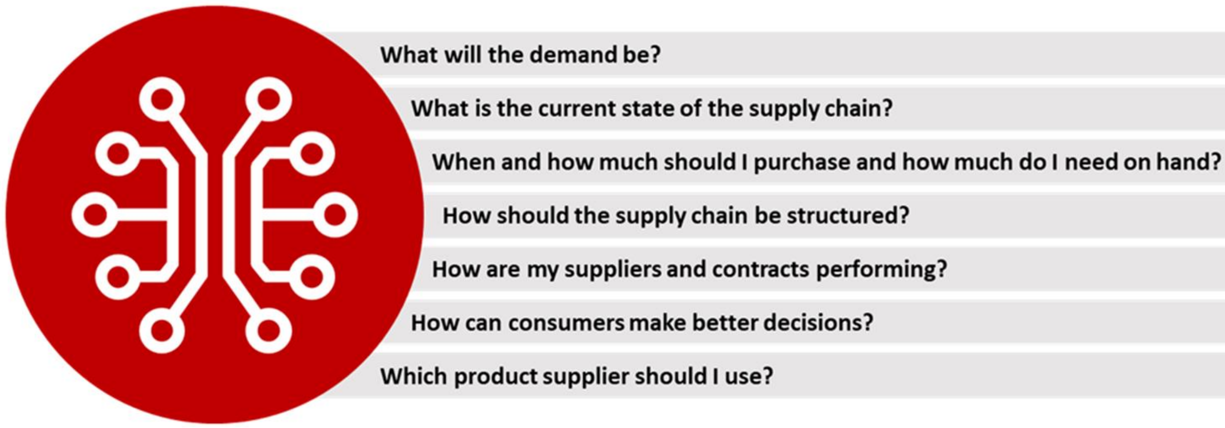
By deploying DSS solutions which use one or more of these mechanisms, each DSS component can directly improve decision-making where it is used. These benefits accumulate and as more DSS are used across the supply chain, the overall system becomes more streamlined, more reactive and asset-light. This is a result of DSS making better-informed decision-makers, establishing additional decision-makers, creating more choices and increasing the options for a given choice.

Transformative opportunities

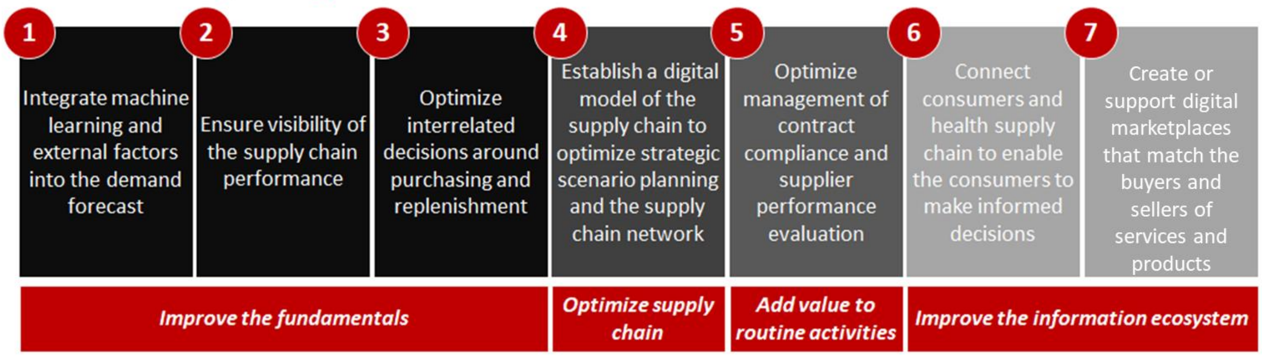
DSS solutions can be widely leveraged across the supply chain and the area of greatest impact will depend on the specific supply chain's maturity and improvement priorities. However, we have identified 7 key PHDC supply chain questions and 7 investment-ready opportunities for DSS to help answer them:

[1] Cited in Green 2018
[2] Adapted from Power 2019
[3] We define use cases broadly as the way a user leverages technology within a specific context.

Top Supply Chain Questions for DSS



Investment-Ready DSS Opportunities



Guiding Principles for DSS

Despite the many challenges, the number and variety of successful projects show that success is possible. There are many paths to success, however, this research has found four broadly applicable guiding principles for implementing DSS in PHDC:

Value Driven

The DSS should ideally deliver value to all stakeholders, including patients, clinicians, data collectors, government and donors

Easy to Use

The DSS should be easy to adopt for all stakeholders

Design to Share

The value of DSS is maximized if data and results can be shared across the supply chain to enhance end-to-end collaboration

Plan for Long Term Success

A plan for the long-term sustainment of success is essential

Call to Action

For supply chain professionals, the most important step in the DSS journey is to begin systematically using data in decision making. Small steps contribute to the cultural shift toward using data in decision making, trusting DSS type systems, and creating the incentive to collect good data.

While supply chain professionals are central to driving DSS uptake, actors beyond the supply chain also have a key role:

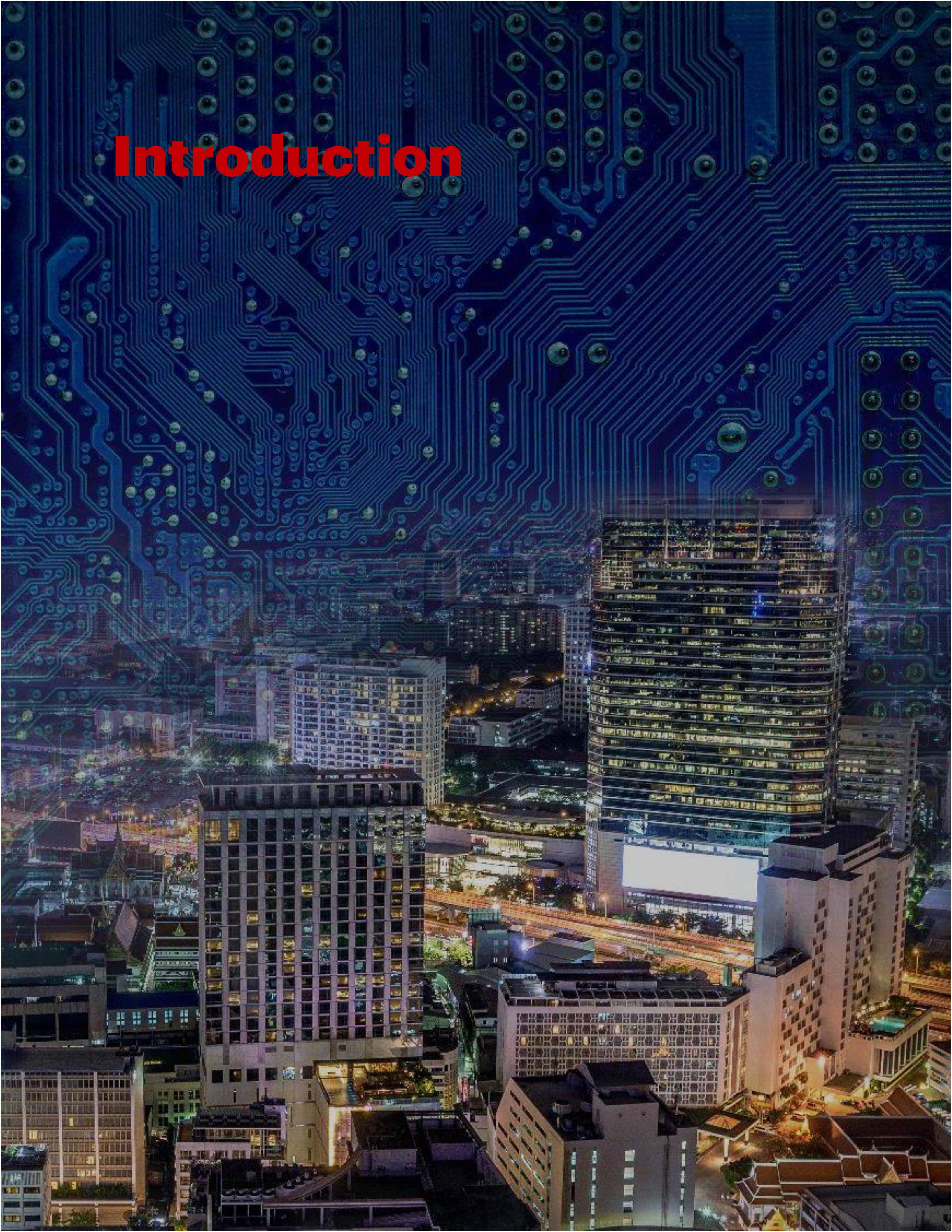
Governments have a mandate to drive change and must shape the information ecosystem in a way that allows DSS uptake.

Funders can provide the resources required to make targeted investments in DSS that help to drive iterative improvement in PHDC supply chains, combine investments in state-of-the-art data collection with state-of-the-art DSS and contribute to the information ecosystem by creating incentives for interoperability.

Software Development Organizations have an important role in ensuring the interoperability of their systems and, wherever possible, sharing with the global community.

Implementing partners have a key role in managing the DSS change journey and ensuring that DSS investments are as effective as possible by managing the parallel process and organizational change.

Introduction



Background and purpose of the report

Efficient supply chain management is critical to secure the performance of the public health sector and secure access to essential medical products. Decision-makers across public health supply chains are responsible for managing the constant risk that life-saving products will not be available when and where they are needed. This is a complex task involving an entire ecosystem of people, processes and technology.

A recent Accenture cross-industry survey of supply chain leaders found that 3 in 4 agree that greater investment in new technology is the fastest path to becoming a leading supply chain industry disruptor, and 72% have seen revenue growth or increased profitability as a result of leveraging intelligent technologies.[4] Decisions Support Systems (DSS) are one such promising application of technology. DSS are computer-based tools that help us use data in decision making, particularly helping supply chain decision-makers deal with complexity and risk. Some leading examples of DSS include:

- UPS´s On-Road Integrated Optimization and Navigation (ORION) algorithm auto-plans the daily routes for its 55,000 drivers in the USA.[5]
- DHL´s platform Ocean View provides near real-time updates on the location of freight at sea.[6]
- Global Family Planning Visibility and Analytics Network (Global FP VAN) enables supply chain data visibility and collaborative decision-making between government and global procurers.[7]

Many leading organizations managing global or developed country supply chains are leveraging DSS to deal with the inherent complexity of supply chains and manage their risk. At the same time, many public health supply chains in developing countries continue to use manual decision-making processes,[8] although opportunities exist to improve decision making with technology.

This contrast is the motivation for this research: ***Are there opportunities to use DSS to transform public health in developing countries (PHDC) and improve global health outcomes?***

This research aims to advance health outcomes in developing countries by highlighting the opportunities DSS represent and understanding the path to their implementation. Specifically, the three objectives of this report are to:

1. **Scan the landscape:** Review the current use of DSS in supply chains to understand successes, challenges for implementation in PHDC supply chains, and key approaches to overcoming these challenges.
2. **Build the Case for DSS:** Define the transformative impact of DSS on public health supply chain outcomes.
3. **Identify Investment-ready DSS**: Recommend investment-ready and promising applications of DSS in PHDC supply chains for various maturity levels. Develop a 'DSS Evaluation Framework' to support stakeholders to prioritize DSS investments.

The results of this research show that there are real opportunities for DSS in PHDC supply chains. In fact, many applications of DSS are already being used, particularly in increasing visibility across supply chains.

Given the existing investment in this type of DSS in PHDC supply chains, the focus of this research is advanced DSS that add value beyond reporting the current state of the supply chain. Some examples of advanced DSS are systems that identify consumption trends, demand forecasting, warehouse optimization, recommend actions and automate decisions. These are equally achievable and promise

[4] Accenture 2018
[5] UPS 2019
[6] DHL 2017
[7] Reproductive Health Supplies Coalition 2019
[8] See for example Yadav, Stapleton & van Wassenhove 2010 and Yadav 2015

to have a profound positive impact on public health outcomes.

Limited infrastructure, human capital, limited data availability and issues with data quality may seem like insurmountable barriers to implementing DSS. This is particularly true of data, which is at the foundation of DSS. In practice data use and data collection are inextricably linked – using data creates the incentive needed for high-quality data collection and shows up problems in the data and data collection process. Organizations in data-poor environments have the most reason to begin their DSS journey as they have the most to gain. Ultimately, the number and diversity of DSS, including advanced DSS, that are already widely used in PHDC supply chains shows that the challenges can be overcome.

Summary of research methods

The research began with a rapid review of DSS use cases[9] in healthcare across both upper middle and high-income countries (developed) and low and lower middle-income (developing) countries, resulting in a catalog of over 150 real-world examples. To carry out the assessment, the Research Team designed a research framework focused on key questions, collected primary and secondary data, synthesized findings and finalized recommendations.

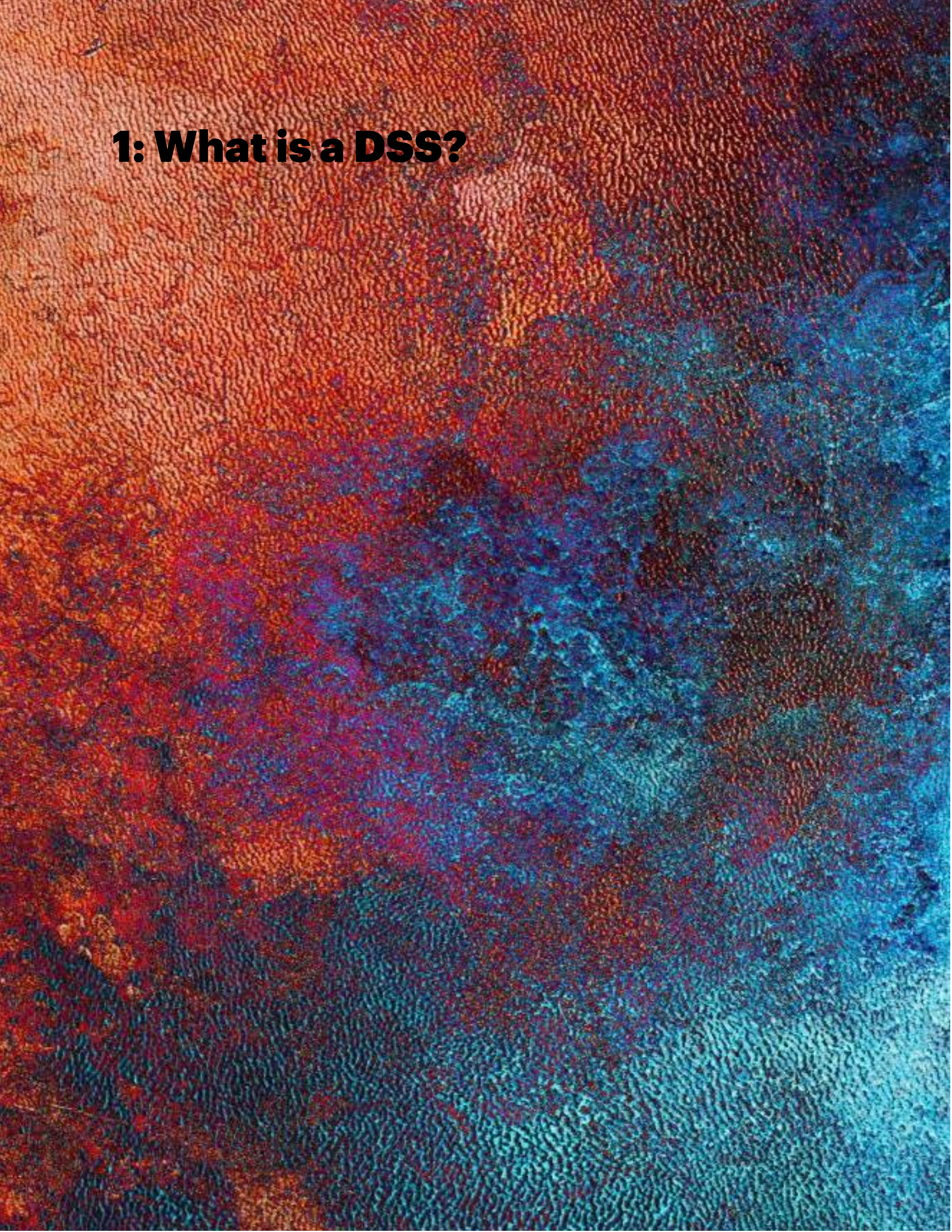
This project has engaged in both primary and secondary research. The primary research includes:

- Semi-structured one-hour interviews with 46 participants. Interviewees include supply chain managers, key opinion leaders/industry experts, implementing international non-governmental organizations (INGOs), private-sector technology providers, foundations, donors and other funders.
- This core primary research is supported by a structured survey, which allows a shallower but wider view of DSS use cases in supply chains with varied maturity and challenges. The survey has received 161 responses, of which 42% are from PHDC supply chains, 9% from other developing country supply chains and 49% from non-public health supply chains primarily based in developed countries.

Secondary research was gathered through desk research across publicly available literature, including books, journal articles, grey literature, thought leadership, industry reports and impact stories. Further details on the research method can be found in Appendix E.

[9] We define use cases broadly as the way a user leverages technology within a specific context.

1: What is a DSS?



Defining DSS

Decision Support Systems (DSS) are computer-based systems or subsystems that enhance the ability to use data to identify where decisions need to be made and to assist in making them.[10]

DSS range in complexity, including 'non-intelligent' (non-learning) calculators, simulation and mathematical models. DSS also include 'intelligent' supply chain capabilities such as complex data science and artificial intelligence models drawing on data held across multiple information management systems (IMS). The unifying characteristic of this diverse set of computer-based tools is that they assist in using data for decision making. The value of the term is the focus it brings to decision making as a specific activity. Box 1 contains a brief discussion of how the term is understood by stakeholders and defined in this report.

Box 1: Defining DSS

DSS could literally mean any systematic process that helps a decision-maker. However, the term DSS is usually reserved for computer-based systems and for systems that specifically support the decision-maker (as in this report). Although the term is now less used in systems and operations research, interviews show that this is fairly close to how supply chain practitioners understand the term.

Because the term DSS is specific to the systems that support decision making, it does not refer to the entire Information Management System (IMS) such as a Logistic Management Information System (LMIS), Enterprise Resource Planning (ERP) system or Customer Records Management (CRM) system. Instead it refers only to those elements that assist the decision-maker interpret and use data.

Reflecting the increasing ability of computer systems to automate decisions (with or without Artificial Intelligence), this report has opted to broaden the modern definition to include automated decision making. This is reflects changes in technology and introduces readers to the more advanced tools that are now available to PHDC supply chains.

Where a DSS fits within a computer system

In a schematic sense, computer systems with a DSS function have at least three elements:

1. **Data collection**: the processes that collect the data, such as manually entering the stocktake into the computer system or automatically collecting data from scanned barcodes.
2. **Data storage:** the information management system(s) that store the data and associated processes that clean, validate and transform the data for use.
3. **Decision support:** the processes that transform the data into information that can be used and understood by decision-makers or other systems. Some examples include processes that calculate stock-out rates, apply a moving average to create a simple forecast or use constrained optimization to identify the best delivery route.

Computer systems may also have two additional elements where they are highly automated:

4. **Decision making:** the processes that make a decision. For example, a system that uses rules and/or machine learning to automatically generates a goods request from a central warehouse when stock falls below a minimum threshold.

[10] Adapted from Power 2019

5. **Execution:** the processes that carry out the decision in full automation. For example a system that automatically initiates the distribution of stores when a request for stores is received, *without requiring human authorization*.

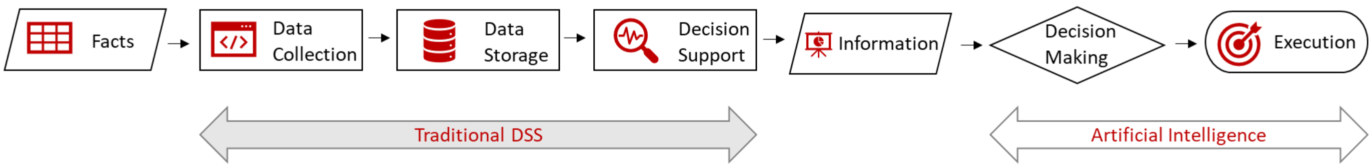


Figure 1: Capabilities of computer systems that include DSS

Traditional definitions of DSS stress that they only assist human decision-makers.[11] The additional layers (4 & 5) reflect the modern reality that computers are increasingly being used to make and execute decisions that were formerly taken by humans. This has been illustratively labeled Artificial Intelligence (AI), as this is where AI technology fits within DSS. However, non-intelligent systems may also automatically make and execute decisions. The decision-making layer (4) identifies the "right" answer (providing the "intelligence"), while the execution layer (5) carries out actions without human oversight. For example, a recommendation system includes the decision-making layer (4), while a prescriptive system that automates the decision includes both decisions-making and execution layers (4 & 5).

Most DSS currently only support human decision making, but as technology progresses, an increasing number of systems will provide the ability to automate a range of decision making and execution. steps. These will not all rely on artificial intelligence and can be rule-bases systems.

Most supply chain IMS include the first three elements listed above, although the DSS is not necessarily highly developed. For example, current inventory reports produced by a Logistics Management Information System (LMIS) are a simple DSS. The DSS can also be a separate tool that draws information from one or more underlying IMS, for example business intelligence platforms like PowerBI, Qlik Sense or Tableau or forecasting tools using formulas in spreadsheets (e.g. CHAI Forecasting Tools) and specific software (e.g. ProQ and Quantimed).

[11] Power 2002

Enabling environment for DSS

The types of DSS that can be implemented in an organization are related to the maturity of the organization´s supply chain system. This maturity refers to how advanced the organization is in performing required supply chain activities across existing processes, technology, organizational structure and skills. For readers not familiar with supply chain information system maturity, Appendix D summarizes USAID´s Supply Chain Information System Maturity Framework, which has been developed specifically in the context of PHDC supply chains.

Importantly, while a basic level of maturity is required, once this has been reached, the implementation of DSS does not necessarily follow the levels of supply chain maturity. In some cases, there will be opportunities to take the *latecomer advantage*[12] to leapfrog to a higher supply chain maturity. This is achieved by directly leveraging newer tools, instead of moving stepwise through intermediary and outdated technology.

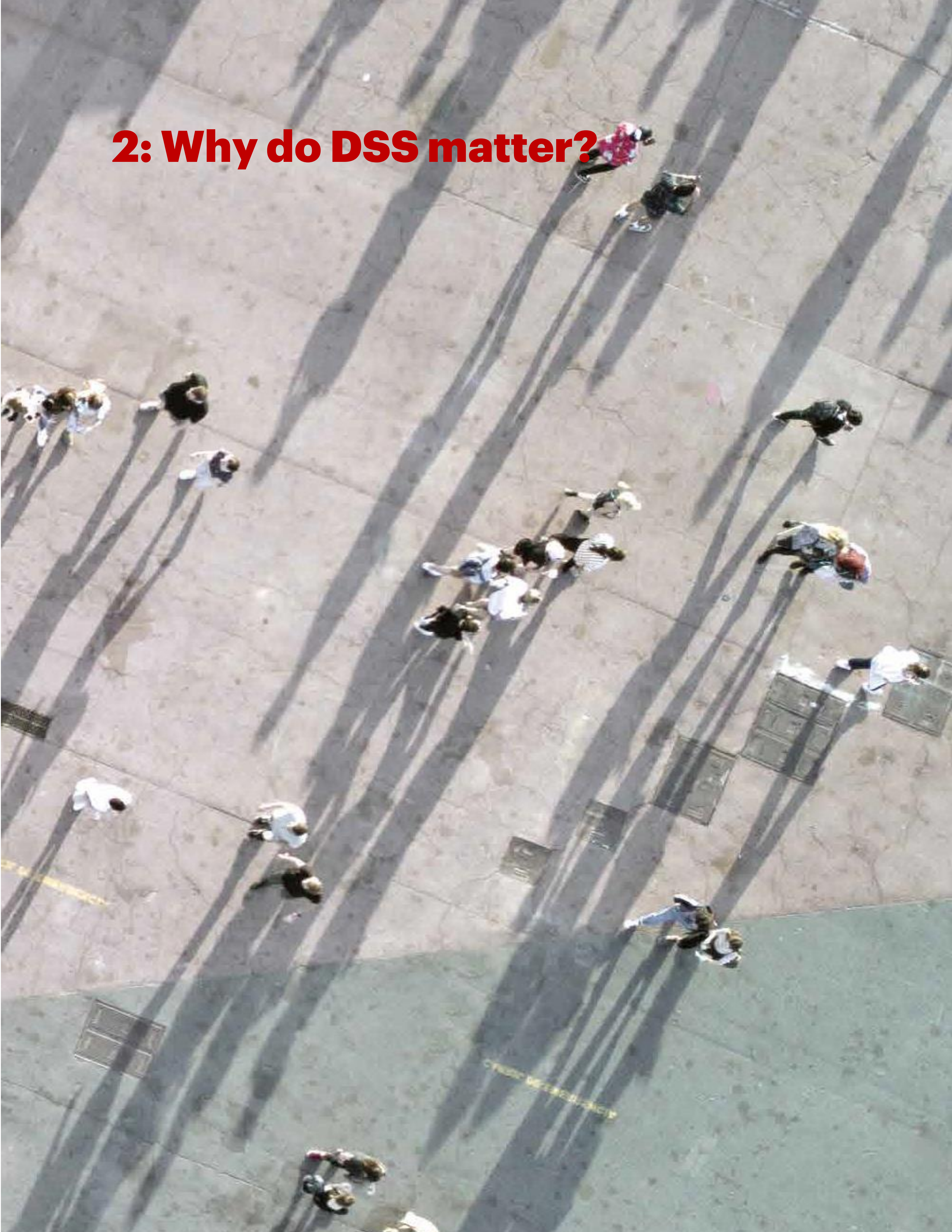
The PHDC context has many challenges to IT system implementation and some specific challenges related to DSS, as explored in Chapter 5. However, as is explored in more detail in Chapter 3, DSS are already widely used in PHDC supply chains. There are many DSS, including advanced DSS, that can be implemented in supply chains with a low level of information system maturity and the enabling environment in most PHDC supply chains is sufficient to begin implementing DSS. While technology alone is never sufficient in overcoming all of the challenges of working in the PHDC environment, the chapters that follow show that DSS are both a valuable and viable area of investment in improving public health outcomes by directly leveraging the latest tools.

Conclusion

DSS describe the computer-based tools that help us use data in decision making. This term has particular value in the focus it brings to the systems and sub-systems that assist in using data in decision making. They are not fundamentally different from any other information system implementation – their defining characteristic is purpose-driven rather than any particular technical requirements. In the same way that the maturity of the supply chain´s information system is related to other applications of IT technology, it also relates to the types of DSS that can be implemented. Like other applications of IT technology it is not necessary to move stepwise through outdated technology and there are opportunities to directly apply more advanced DSS solutions.

[12] The latecomer advantage is the benefit to those who can invest directly in the latest technology without having invested in intermediate steps (including the benefit of avoiding being locked into that intermediate technology or having it affect the development path). See Veblen 1964.

2: Why do DSS matter?



Why do DSS Matter?

The objective of a public health supply chain in a developing country is to improve health outcomes by ensuring the “six rights”: the right goods, in the right quantities, in the right condition, are in the right place, at the right time, for the right cost.[13] This means the coordination of an entire ecosystem of organizations, people, technology, activities, information, and resources and implies many layers of decision making. **The better the decisions, the more effective the supply chain is in ensuring that people have the medical products they need, when they need them.**

DSS are systems specifically designed to improve decision making by helping users incorporate data in the decision-making process. In the words of one interviewee:

“Supply chain DSS are about complexity and risk, and we want to reduce risk across the supply chain. At some point risk is a cost – not necessarily in money but it could be in lives or life quality.” [14]

The complexity means that it can be very difficult for decision-makers to take the right information into account in time to make an informed decision. The risk is that medical products will not be available where they are needed, when they needed. By helping supply chain decision-makers make better decisions, DSS have a direct impact on public health outcomes.

DSS bring direct benefits to the supply chain function where they improve decisions. They also have a long-term cumulative effect on the overall supply chain as they incrementally improve efficiency and the ability of the supply chain to respond to events.

The first section of this chapter sets out a framework of five focus areas by which DSS directly help the decision-maker to 1) connect and integrate, 2) observe and describe, 3) sense and predict, 4) learn and adapt, and 5) optimize and automate.

The order in which these benefits are discussed does not necessarily reflect a typical investment path. In fact, investments in multiple focus areas are usually made at the same time. This is particularly true of projects that connect and integrate, as in practice these projects support other DSS and are not investments that are usually made on their own.

Rather than reflecting the direct benefits in a specific focus area, a typical DSS journey is related to the combined cumulative effects of the many incremental improvements to the supply chain. This is outlined in the second section of this chapter, which describes both the broader effects of DSS on the supply chain and the provides a framework for understanding the DSS journey.

The language of DSS can include many computer science/ data science terms, and so the definitions of the key terms used in this report have been provided below in Box 2.

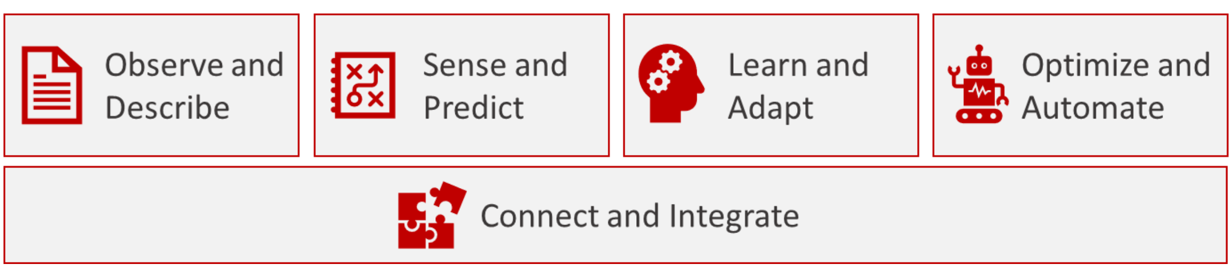


Figure 2: DSS focus areas

[13] John Snow, 2017

[14] Anonymous interview

Box 2: Computer/data science terms

The vocabulary of computer/data science may not be familiar to many outside these fields and many terms are used interchangeably without being clearly defined. To aid in the discussion, some of these terms and definitions used in this report are provided below:

Algorithms are a set of logical actions performed in a specific order to solve a problem.

Artificial Intelligence (AI) is the use of computers for automated decision-making to perform tasks that normally require human intelligence.[15]

Machine learning is the automated detection of meaningful patterns in data.[16] Machine learning can be used to generate (some of) the logic used by an algorithm without requiring explicit definition by a human, i.e. it can be used as a basis for AI.

Supervised machine learning uses data that is assumed to manifest the true/correct relationship between factors/variables to learn the logic of that relationship. Examples of this type of algorithm include linear/nonlinear regression, logistic regression, support vector machines, decision trees, random forests and artificial neural networks.

Unsupervised machine learning discovers unknown relationships in data by inferring the relationship between factors/variables without having an example of the correct relationship. Examples of this type of algorithm include K-means, DBSCAN, t-SNE, Principle Component Analysis and Apriori.

Reinforcement machine learning uses a structure of rewards and punishments (e.g. winning or losing a game of chess) to find relationships in data that increase the measured rewards (and/or reduce measured punishments).

Clustering is the process of dividing data points into groups such that data points within the groups are more like data points in the same group than they are to data points in other groups. There are both unsupervised and supervised machine learning clustering algorithms.

Natural language processing (NLP) identifies the meaning of keywords and phrases in human language (e.g. text or spoken language) and translates this into a language that can be understood by computers.

[15] Oxford Dictionary, 2018 cited in USAID n.d.
[16] Shalev-Shwartz & Ben-David 2014

DSS impact areas for improving the supply chain

DSS can improve supply chain performance by directly helping decision-makers in five ways. The framework below is based on the Accenture Digital Supply Chain Best Practice framework of the improvement potential of the supply chain, which has been modified to reflect this report's context. Figures below are illustrative, based on Accenture client examples.

1. Connect and Integrate

This type of DSS connects data from sources across the supply chain and is typically an enabler for realizing the full value of the other areas. Some examples of how information from different sources are combined include:

- A Business Intelligence tool that connects to multiple IMS to provide basic KPIs.
- A dashboard that can be accessed by all actors in the supply chain showing real-time data from the manufacturer about delays or changes in the manufacturing plan.

Connect and Integrate

11%
Reduction in operations cost by **multiple system and sensor data integration in a dashboard**

25%
Improved Estimated Time of Arrival accuracy by **multiple system integration and machine learning**

2. Observe and Describe

These DSS describe what is happening now and what has happened. Some examples include:

- An Excel spreadsheet calculating stock-out rates.
- An LMIS that provides an overview of the current level of inventory at different warehouses.
- A business intelligence tool integrated with a LMIS that provides a real-time overview of consumption, inventory and goods-in-transit.

Observe and Describe

5% - 15%
Reduction in inventory by **increased lead time visibility**

3% - 5%
Reduction in transport cost by **increased product visibility**

3. Sense and Predict

This type of DSS assists decision-makers understand what will happen. It helps users to generate forecasts (e.g. predict future demand or order calculation), compare scenarios of two or more predictions, and simulate options and consequences. At their best they enable the decision-maker to respond to disruptions before they occur. Examples include:

- An Excel spreadsheet that calculates a moving average from historical inventory data to provide a demand forecast.
- A forecasting tool that takes into account current data and external variables like population growth to estimate demand using supervised machine learning like linear regression.

Sense and Predict

29% - 37%
Reduction in inventory cost by **inventory forecasting using machine learning**

US$200M
Reduction in supply chain costs by **demand forecasting using machine learning**

4. **Learn and Adapt**

In this type of DSS, the results of previous decisions are recorded and analyzed to identify how decisions can be improved. Some examples include:

- An Excel spreadsheet that tracks the performance of providers against their cost, quality and reliability to assist in future provider selection.
- A tool that identifies wastage and automatically recommends alternative distribution decisions.

Learn and Adapt

10%
Increase in demand forecast accuracy by **continuously identifying new demand patterns**

5. **Optimize and Automate**

This type of DSS optimizes a decision with respect to a set of conditions. The result can then be used to automate the relevant functions of the supply chain.

- A spreadsheet that sorts suppliers based on value for money allowing the decision-maker to see the optimal mix of suppliers.
- An automated procurement process based on real-time consumption data.
- Transport planning software that optimizes the transport route of each vehicle to meet required delivery dates and recommends how the supplies are loaded into the transport to optimize the fill rate.

Optimize and Automate

5% - 9%
Reduction in distribution cost by **network design optimization**

45% - 60%
Improvement in staff productivity due to **intelligent and automated order management**

Many DSS improve the supply chain through more than one mechanism. The Global Family Planning Visibility & Analytics Network is a good example in the PHDC context, which helps decision-makers to observe and describe by connecting and integrating data through a shared platform for governments and global procurers.[17]

DSS are already widely used within PHDC supply chains and many readers will be able to recognize current tools that meet the definition of DSS. The opportunities presented by DSS are not so much in introducing ways of working that are entirely new or have never been used within the supply chain. Instead the opportunities lie in exploiting existing mechanisms to improve the supply chain. This means expanding the use of existing DSS and leveraging technological advances to further improve decision making across PHDC supply chains.

[17] Global Family Planning Visibility and Analytics Network 2019

Where are organizations investing?

To support this research, this project undertook a Survey of Decision Support Systems with responses from 161 supply chain management practitioners and consultants. Across all supply chains, survey respondents who have implemented an advanced DSS indicated that their most recent projects aimed to help decision-makers Observe and Describe (48%), Sense and Predict (36%), Optimize and Automate (17%) and Connect and Integrate (5%). All responses are shown below in Figure 3.

The results indicate that actors are still heavily invested in describing and visualizing the current performance of the supply chain, in addition to adding to more advanced analytics and machine learning to sense and predict events (e.g. demand forecasting). Optimization and automation is also an area that is growing in importance, often targeting niche supply chain functions (e.g. automatic ordering, warehouse pick and pack). Systems that connect and integrate support other supply chain functions and no respondents indicated that advanced DSS only improved the supply chain through this mechanism. No investment was observed in systems that learn and adapt. These systems rely heavily on recommendations and prescriptions and imply a very high level of trust and acceptance of technology in the supply chain, potentially explaining why they are not currently a focus for investment.

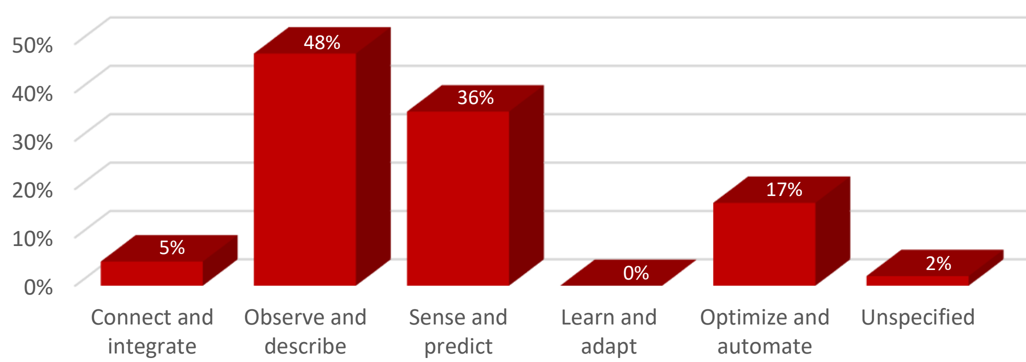


Figure 3: Type of most recent advanced DSS implemented, %

Source: Survey of Decision Support Systems for Supply Chain Management Practitioners and Supply Chain Consultants
Note: Proportion of all respondents who had implemented advanced DSS. Respondents may indicate more than one category and so totals may sum to more than 100%.

DSS and wider changes in the supply chain

DSS have broader effects on the supply chain, beyond the direct effects they have on the function in which they are implemented. These effects are cumulative and over time fundamentally change the way in which supply chains operate. For illustrative purposes, these can be shown as five conceptual steps in the continuum of this change. These are illustrated in Figure 4, which is followed by a brief description of each step. A more detailed description can be found in Appendix B: Applications of DSS.

The DSS Journey[18]

These five conceptual steps mark milestones on the continuum of DSS journey from ad-hoc to proactive supply chains. This is not directly related to the sophistication of individual DSS, but to the combined effect of DSS on data use and availability in a supply chain´s information ecosystem.

1. Ad-hoc: Data is registered in a paper-based or electronic information system on an ad-hoc and manual basis. The decision-makers are **unable to consistently use data in routine decision-making, monitor the supply chain or consistently react to exceptions.**

2. Reactive: Transactional data is entered in an electronic information system. DSS provide descriptive historical information and support some routine decisions (e.g. through calculations and recommendations) to some silos within the supply chain. Decision-makers use DSS **to support routine decisions, monitor activities within their node** and to manually identify exceptions.

3. Responsive: Functional information systems are integrated across the supply chain. DSS provide descriptive historical information and support many routine decisions (e.g. through calculations and recommendations) using data from nodes along the supply chain. Decision-makers use DSS to **support routine decisions, monitor activities in the end-to-end supply chain** and to manually identify exceptions in (other) nodes that will affect their node.

4. Event driven: DSS are used to automate routine decisions, monitor activity and alert decision-makers to exceptions in the supply chain requiring their attention. **Decision-makers focus on exceptions rather than routine tasks to mitigate the impact of exceptions further up the supply chain on their node.**

5. Proactive: DSS predict future events before they occur and automatically integrate it into automated routine tasks (e.g. demand sensing). **Decision-makers focus on future exceptions to mitigate them before they impact the supply chain.**

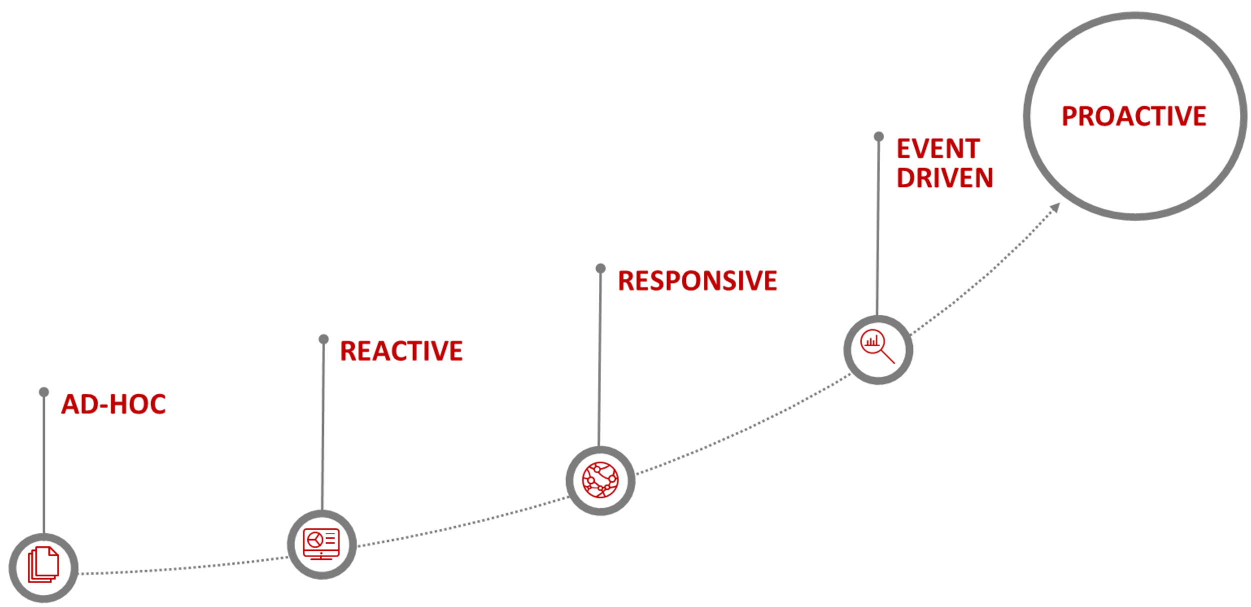


Figure 4: Supply Chain Transformation

[18] For more detailed information and examples of decisions supported by DSS at each step, see Appendix C: DSS journey.

DSS as drivers of fundamental change

Driving these changes are four underlying changes that the cumulative implementation and use of DSS have on supply chains.

1. More informed decision-makers

The first change in the supply chain we observe with the increasing adoption of DSS is the use of information by more decision-makers. Where information may previously have been available only to higher-level managers, DSS can bring that information to decision-makers throughout the supply chain, right down to the point of sale/service (POS).

DSS can also empower the end consumer to make informed decisions about consuming based on information about origin, quality and correct use. It can also allow them to make informed decisions about their last-mile arrangements, i.e. their choices in traveling to collect or consume medication. This democratization of information promises small efficiency gains at each decision point and potentially an enormous change in the efficiency of the system as a whole.

2. More decision-makers

There is often a discussion in implementing DSS about the need to provide different information at each tier of the supply chain. This is true in the sense that different actors need different information on which to base different decisions. It should not be confused with the idea that central decision-makers *should* have access to more information than lower tiers. As an increasing number of people gain access to supply chain information there is an increasing number of people with enough information to become decision-makers.

At the same time, the increasing use of DSS and concurrent improvements in data collection and sharing allow for greater centralization. This is caused by increased access to information at the top of the supply chain that was previously only available at a lower layer. It may seem counterintuitive to be able to both centralize and devolve decision-making. It is difficult to predict the end result of changing the costs and benefits of making decisions at the very top and very bottom of the supply chain. What is clear is that there is less need for decision making in the intermediate layers. As in leading private sector firms in developed countries, this makes it possible to trim decision making nodes (i.e. district or regional decision-makers) from the middle tiers of the supply chain.

3. More choices

Like all technological advances, the increasing adoption of DSS brings more of the physical environment under human control. In the supply chain, an example of this is being able to respond to events that were previously not identified until long after they had occurred, such as an alert to the predicted failure of a refrigeration system or an imminent change in the demand pattern. This creates the ability to choose where previously no choice existed, for example, the choice to carry out proactive maintenance or replenishment. These are examples of a broader trend in the expanding number of choices in the supply chain.

4. Expanded option set

The uptake of DSS also expands the options available under any given choice. The clearest examples are the opportunities presented by digital platforms that match buyers and sellers (Logistimo/Tusker, eBay, Uber, Airbnb, JustEat, Etasker, etc.). In public health supply chains, these present solutions at each end of the supply chain. At the very beginning of many supply chains, online marketplaces are providing more choices and the potential to provide a model of how to increase the number and visibility of options (suppliers) in PHDC supply chains. At the very end of PHDC supply chains, solutions like last-mile apps are already being used to increase distribution options.

The net effect of these changes in terms of structure and improved efficiency are more responsive supply chains. As supply chains become more agile, they require fewer scheduled manual processes that monitor all supply chain activities. Instead, there is only a need to respond to or eventually pre-empt specific events that might disrupt the flow of goods in their supply chain. This allows supply chain managers to focus their attention on exceptions. Efficiencies in supply and demand planning reduce the need to carry inventory, hollowing out the number and size of the physical storage required in the supply chain. As described above, there is a similar trimming of the decision-making nodes along the supply chain. Combined, these represent a trend towards more responsive, more streamlined and asset-light supply chains.

Conclusion

Supply chains have a direct impact on public health outcomes and decision-makers are constantly managing the risk of medical products not being available when and where they are needed. At the same time, the supply chain is inherently complex, making it difficult to ensure that the right information is used in decision making.

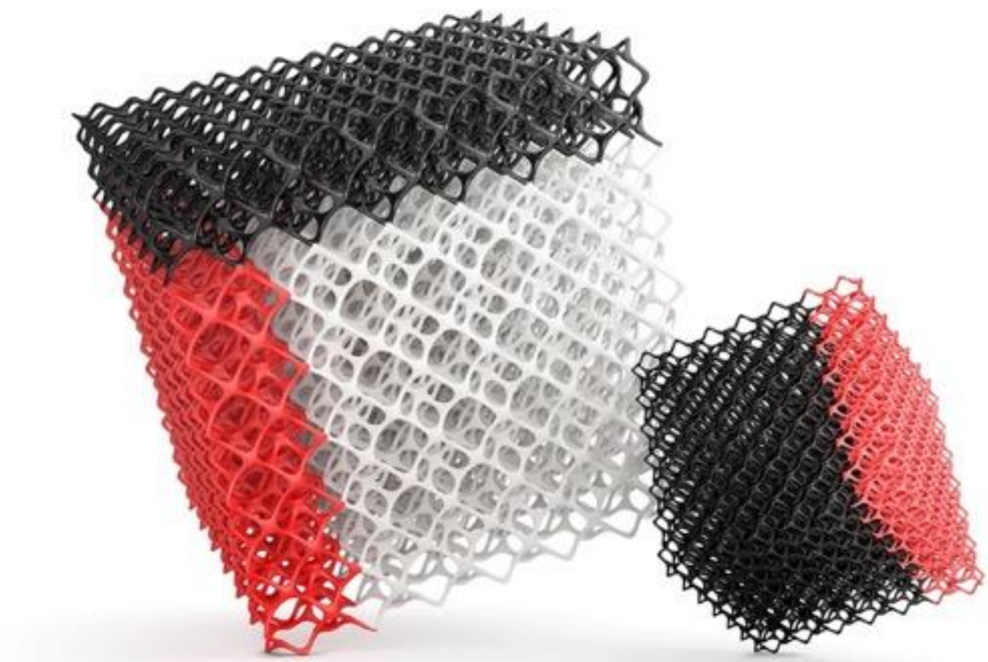
DSS help supply chain decision making by making it easier to incorporate data into decision making. They do this through at least one of five mechanisms that directly improve decision-making in the supply chain functions where they are implemented. Individually these complement existing supply chain systems and do not represent a drastic shift in ways of working in the supply chain.

DSS also have broader effects on the supply chain by iteratively improving the information ecosystem. These benefits are cumulative and affect the way in which information is used across the supply chain. While the change exists as a continuum, it is conceptually possible to mark milestones in terms of how much information is available and how it is used. This helps conceptualize the shift from ad-hock to proactive supply chains.

Driving these changes are observed effects in terms of how much information is available and who has access to that information. In the long term these changes drive the shift towards a proactive supply chain. They also drive a structural shift to towards more responsive, more streamlined and asset-light supply chains.

Because these effects are cumulative, investment in DSS is best thought of as part of continuous improvement. Each individual implementation or improvement to a DSS brings great benefits to the supply chain and so to public health. By continuously improving the supply chain through cumulative DSS implementation, the overall effects of DSS represent a truly transformative opportunity for public health supply chains in developing countries.

3: Current use of DSS and lessons from other contexts



Global and developing country companies are investing in real-time visibility for their end-to-end supply chains, as well as incorporating analytics and machine learning in their daily operations. In contrast, PHDC supply chains encompass a variety of supply chain maturities and DSS uptake, due to the many complexities and challenges in this context. While the majority of developing countries are still investing in harmonizing data and visualizing information, several innovative solutions implemented in both the public and private sectors incorporate advanced analytics.

This chapter presents an overview of the current landscape of DSS use cases across supply chains and provides examples of how some of the use cases are deployed in PHDC supply chains.

The chapter is structured around the key supply chain functions, shown in Figure 5 below, and the key questions for decision-makers in these functions.

Table 1 (over page) provides a summary of current DSS use cases for each of these functional areas. The darker shaded cells show current key DSS investment areas for the non-PHDC private sector, while lighter shaded cells highlight current key examples from PHDC supply chains. Following the summary, a more detailed overview is presented for the key questions that face decision-makers and where this shows potential opportunities for DSS in PHDC supply chains. The more detailed landscape used to develop this overview can be found in Appendix B: Applications of DSS.

Figure 5: Key Supply Chain Functions in PHDC supply chains and non-PHDC supply chains

☐ Limited investments non-PHDC sector and PHDC sector ☐ Key investment examples PHDC sector ☐ Key investments non-PHDC sector

	Connect and Integrate	Observe and Describe	Sense and Predict	Learn and Adapt	Optimize and Automate
Demand Planning	Connect external sources to inform the forecast	View historical or current consumption data (or proxy consumption data)	Forecast demand for a product	Continuously discover new variables/factors affecting the demand	Choose the profit-maximizing price
Inventory Management	Connect data on inventory levels across warehouses to decide stock movement	View historical or current level of Inventory	Monitor stock levels and predict future stock levels	Identify factors leading to stockout/low service levels	Dynamically set minimum/maximum inventory
Supply Planning	Leverage Storage and routing to identify mismatches in supply and advise on rescheduling	View goods in the pipeline and compare with shipments and demand forecast	Predict potential mismatches in supply/demand based on forecasted market changes	Learn from experiences with a supplier and recommend alternative suppliers	Choose optimal combinations of products that are typically consumed together
Warehouse Management	Connect all warehouses in the network to allocate storage	View historical or current stock levels of the warehouses and product characteristics	Predict the future storage needs	Learn from seasonality and market trends to recommend warehouse allocation	Choose optimal storage capacity
Distribution Management	Integrate external data in dynamic route recommendation and prediction	View historical or current data on product flow and be notified of delays	Continuously recommend optimal routing and predict delays in arrival	Learn from past distribution what contributed to delays	Identify nodes that can be eliminated to improve network performance
Quality Assurance	Connect with supplier database to ensure quality Track goods to avoid counterfeiting	Monitor conditions (e.g. temperature) across the supply chain (automatically or manually)	Predict equipment failure and need for maintenance	Learn from past conditions that led to damaged products	Identification of most optimal warranty management policy
Risk management	Integrate external data to predict risk events	Monitor risk events as they are occurring (automatically or manually)	Predict risk events based on internal data and provide recommendations on mitigation	Adjust the supply chain based on previous risk events	Choose suppliers based on automated analysis of risk

Table 1: Summary of current DSS examples

Across all survey respondents, inventory management is the area where we see the most investment in advanced DSS. This is followed by projects investing in multiple system modules, which captures a wide range of functions of the supply chain from demand planning to distribution.

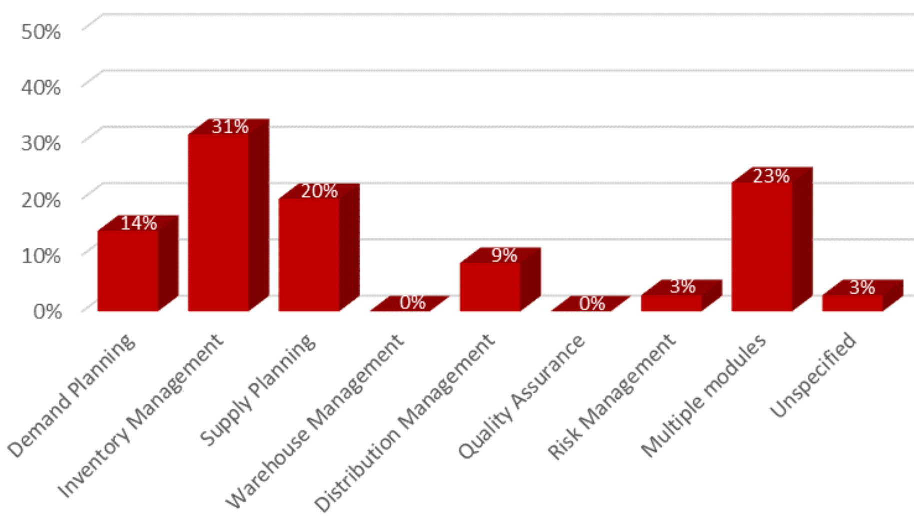


Figure 6: Type of most recent advanced DSS implemented, %

Source: Survey of Decision Support Systems for Supply Chain Management Practitioners. Note: Proportion of all respondents who had implemented advanced DSS. DSS can include multiple functions.

What will the demand be?

To purchase the correct amount of supplies, decision-makers need a vision of what demand will be in the future. At the lower end of digital maturity are systems that estimate demand using stock depletion. For more digitally mature organizations, historical or near real-time consumption data is used to manually estimate demand.

Around 14% of survey respondents who have implemented an advanced DSS indicated that their last project related to demand.

Statistical or machine learning algorithms are used in state-of-the-art DSS to predict future demand, eliminating the need for manual calculation. External factors influencing demand are included, such as demographic trends or disease patterns.[19]

State-of-the-art Case: Advanced statistical demand forecasting

A major global pharmaceutical company struggled with correctly identifying their demand, resulting in inaccurate inventory levels and high operational costs.

The company expanded its time-series algorithms with machine learning algorithms that were able to detect non-linear pattern changes in historical sales data. These were used to improve the demand forecast. A dashboard was also developed in Tableau to showcase the results in a user-friendly manner. For a certain subset of products, the analysis improved the forecast accuracy by 40%.[20]

[19] Rich et al. 2010: p3
[20] Accenture client experience

What do I have on hand?

The supply chain manager needs to know the stock on hand to purchase the correct quantity of supplies that meet demand. At the lower end of digital maturity, stock depletion is manually updated in an electronic information system. For more advanced organizations, the DSS monitor the current inventory level against the target inventory level and notifies the decision-maker when there is a risk of stock out or excess/obsolete inventory.

Around 30% of survey respondents who have implemented an advanced DSS indicated that their last project related to inventory, making inventory a key investment area.

State-of-the-art DSS advise the decision-maker on whether any immediate reallocation of inventory across the network is required to meet forecast demand.

State-of-the-art Case: Advanced statistical inventory forecasting

A major mobile telecommunications company using the same stock target settings for each product struggled with high inventory levels and a high level of obsolete stock.

The company built a statistical model to calculate retail stock levels based on individual Supply Keeping Units (SKUs) at each store. The model incorporated demand history and variability to determine the optimal stock level and target service level depending on the popularity of the product. As a result of the new model, the company reduced total retail inventory by 40%, accounting for over US$11.5m.[21]

What do I need?

To meet estimated demand, the supply chain manager needs to know which supplies to order and the quantity needed. Around 20% of survey respondents who have implemented an advanced DSS indicated that their last project related to supply, making supply a key investment area after inventory. For organizations with a lower level of maturity, the DSS advise the decision-maker on the number of supplies that should be ordered and when they should be ordered, based on the demand and inventory forecast.

Examples of state-of-the-art are DSS that use machine learning models to recommend a combination of items that could be purchased together given purchase history. DSS are also used to monitor supplies in the pipeline and alert the decision-maker if the supplies in the procurement plan do not match anticipated demand and whether to reschedule any specific deliveries.

State-of-the-art Case: Intelligent order management

The supply chain of a healthcare company providing spare parts to hospitals required a high degree of manual intervention to follow up on orders that are temporarily out of stock (i.e. backorder) and to decide on the right order fulfillment action.

The company invested in a supply chain solution using artificial intelligence to automatically determine the optimal order fulfillment action, integrating insights from replacement frequency and spare part performance indicators. The solution lead to a 45% to 60% improvement in staff productivity.[22]

How are my suppliers and contracts performing?

The supply chain manager needs to have an overview of how the suppliers and the contracts are performing to secure a cost-efficient and stable supply of goods. In non-PHDC supply chains we see specific DSS applications that address this question.

[21] Accenture client experience
[22] Accenture client experience

At the lower end of digital maturity, supplier KPIs are defined in an information system and actual performance data are added and benchmarked manually against the KPIs. State-of-the-art DSS capture data on the performance of the suppliers and notify the decision-maker if a supplier is underperforming. In addition, the DSS can integrate external market intelligence on market prices to estimate how a change in the price impacts supplier contracts.

State-of-the-art Case: Automated supplier contract monitoring

A global oil company currently has a large market intelligence team monitoring the market prices of key raw material (e.g. steel) to calculate how the price impacts the contracts with their suppliers.

The company feeds market intelligence data from an external provider to its internal end-to-end supply chain management tool and has linked it to the supplier contracts and orders. The market intelligence team is notified immediately if a change in market price affects the current contract and the monetary impact.[23]

How do I store the supplies?

The supply chain manager needs to store the supplies efficiently to avoid stock-outs and obsolete stock. For organizations with a lower level of digital capabilities, DSS register stock status and the location of goods in the warehouse. For more digitally mature organizations, DSS determine the best location for stock in the warehouse and advise the decision-maker on which supplies to ship next.

State-of-the-art DSS also provide warehouse network optimization, which includes the ideal warehouse location, and the amount and type of supplies to be located at each warehouse.

State-of-the-art Case: Operations simulation

One of the largest retailers in the US struggled to design warehouses to manage its slow-moving products across stores. It aimed to consolidate these products upstream and reduce inventory at the store level.

The company invested in a simulation model to estimate the impact of new warehouses upstream based on a change in product mix, change in frequency of deliveries from upstream distribution centers to regional centers to stores, change in replenishment strategy and increase in future store demand. Several scenarios are run on top of the baseline model, improving allocations to stores, service levels and avoiding markdowns for slow-moving items. In Accenture´s experience from similar projects, optimizing network design has reduced distribution costs by 5% to 9%.[24]

How do I distribute the supplies?

To ensure on-time product delivery, the supply chain manager needs to optimize distribution. At the lower end of digital maturity, the transport flow is monitored by DSS through either manual or transactional data capture at every supply chain node. For more advanced organizations, DSS monitor near real-time stock movements and generate alerts if there is a risk of delay.

Around 9% of survey respondents who have implemented an advanced DSS indicated that their last project related to distribution, making distribution a relatively low priority investment area.

DSS that are considered state-of-the-art determine the optimal transport route and predict the time of arrival, integrating factors such as cost, road conditions and seasonality. The route optimization tool also includes demand data and notifies the decision-maker if a transportation ramp-up is needed to meet future demand.[25]

[23] Accenture client experience
[24] Accenture client experience
[25] Rich et al. 2010: p3

State-of-the-art Case: Intelligent Estimated Time of Arrival (ETA)

A global high-tech equipment producer struggled to achieve end-to-end visibility due to multiple internal and external systems and dependence on carrier data.

The company integrated multiple systems into a common data lake and deployed machine learning algorithms to predict delivery times in near real-time. The prediction model runs every five minutes to incorporate messages received by third-party logistics providers. The solution improved the estimated time of arrival accuracy by around 25%.[26]

How do I ensure the quality of the products?

To minimize the risk of substandard goods delivered to the consumer, the supply chain manager needs to control the quality of the products. Mature digital companies employ DSS to monitor the condition of equipment and predict when the equipment requires maintenance or replacement.[27] DSS are also used to monitor the condition of the supplies in transit or storage. Cold chain provides a common example, where sensors monitor temperatures and alert the decision-maker where exceptions are detected.

State-of-the-art DSS provide end-to-end track and trace authenticity monitoring through a QR code, RFID or barcode, leveraging GS1 or other standards. If there is a deviation from the original code, the DSS notifies the decision-maker. The faulty batch can be backtracked along the supply chain and recalled if necessary.

State-of-the-art Case: Preventing counterfeit pharmaceutical goods

A global transportation company wanted to overcome the challenge of counterfeit medication entering the supply chain.

The company invested in a blockchain-based track-and-trace serialization prototype that included a global network of nodes across six geographies. The solution documents each step that a pharmaceutical product takes in the supply chain and verifies the authenticity of the medication through the serialization number. The project illustrates how blockchain can be used to capture all logistics activities linked to a specific item and ensure this information is made secure, transparent and immediately available.[28]

What are my risks?

To minimize disruptions to the supply chain, the supply chain manager needs to address risk. In non-PHDC supply chains, we see specific DSS applications that address this question. State-of-the-art DSS monitor external risks (financial, reputational, natural disaster, human-made, geopolitical, cyber) and notify the decision-maker if there are any risks connected to the orders or suppliers.

State-of-the-art Case: Intelligent risk monitoring

A large agricultural producer found that unexpected changes in the weather affected their ability to deliver the required food to their clients.

The company implemented a continuous monitoring system to track weather disruption and other risks that could impact the supply chain. The system monitors large external data sets and employs deep learning algorithms to screen and extract relevant risk signals. The system allows the company to act proactively to any disruptions and ensure product delivery.[29]

[26] Accenture client experience
[27] Rich et al. 2010: p14
[28] Accenture client experience
[29] Risk Methods 2019

Are my customers satisfied?

Production companies need to capture customer feedback to secure continuous product improvement. In non-PHDC supply chains, we see specific DSS applications that address this question. State-of-the-art DSS capture customer feedback which is shared with the production company. The supply chain manager can also use this customer feedback to evaluate the product.

State-of-the-art Case: Digital innovation from customer feedback

A global energy management company wanted to increase its responsiveness to client needs and accelerate digital innovation and speed to market.

The company uses analytics-based insight generated from the actual use of their products to determine client needs and required innovations to their existing products. The company uses a framework that allows them to incubate, design and deploy new product innovations. The system allowed the company to reduce the launch time of new digital services by 80%.[30]

Conclusion

DSS are being used extensively to make efficient decisions across demand and supply planning, contract management, distribution, storage, quality assurance, risk management and customer satisfaction. There are many examples of DSS in both PHDC and non-PHDC supply chains. Around 1 in 4 of survey respondents who have implemented an advanced DSS indicated that their last project related to a multi-module implementation, covering several functions in the supply chain. The remaining survey respondents indicated that their last project related to niche investments, targeting one or two supply chain functions.

Many of the larger and established private sector companies are still focusing on achieving end-to-end real-time visibility of the supply chain. The visibility work is often also combined with smaller initiatives and pilots on advanced analytics and machine learning to explore their potential. However, the born-digital companies, such as Amazon and Uber, are at the forefront of incorporating advanced analytics and machine learning directly in the way decisions are made within the supply chain organization. The increasing use of DSS is also driving a shift in the way of working, moving from continuous monitoring to event driven supply chain management. In an event driven supply chain, the automated rules and algorithms monitor the supply chain activity and notify the decision-maker if there is a deviation. The decision-maker reacts to specific events, rather than monitoring all activities.

The current applications and opportunities of DSS in PHDC supply chains also vary widely. Some countries still use paper-based systems to manage the supply chain, while some countries employ either end-to-end solutions or specific niche software solutions to manage the supply chain. Functions where we see many examples of DSS in PHDC supply chains, are demand planning, supply planning, inventory management, distribution management and quality assurance. Contract management, risk management and customer satisfaction are areas where fewer DSS are used.

The current DSS use cases in PHDC supply chains provide inspiration and show opportunities to expand their use across a greater number of countries, health systems and supply chains. The examples of the state-of-the-art technology used outside PHDC supply chains point to areas where there are opportunities for PHDC supply chains to use and adapt DSS to their specific needs.

[30] Accenture client experience

4: Transformative opportunities

DSS have the potential to radically transform the way in which a decision-maker interacts with supply chain systems and improve supply chain outcomes. Where DSS will have the most impact is specific to a given supply chain – particularly considering the supply chain´s maturity and improvement priorities. However, this research has found seven opportunities that address problems commonly raised in interviews, the survey and desktop research. These are presented in this chapter under the heading of the supply chain questions they primarily address.

Figure 7 below presents an overview of the key supply chain questions addressed and the investment-ready applications. This is by no means an exhaustive list and is designed to provide inspiration for continues improvement through DSS implementation and use. A longer treatment of DSS applications and questions that they address can be found in Appendix B: Applications of DSS.

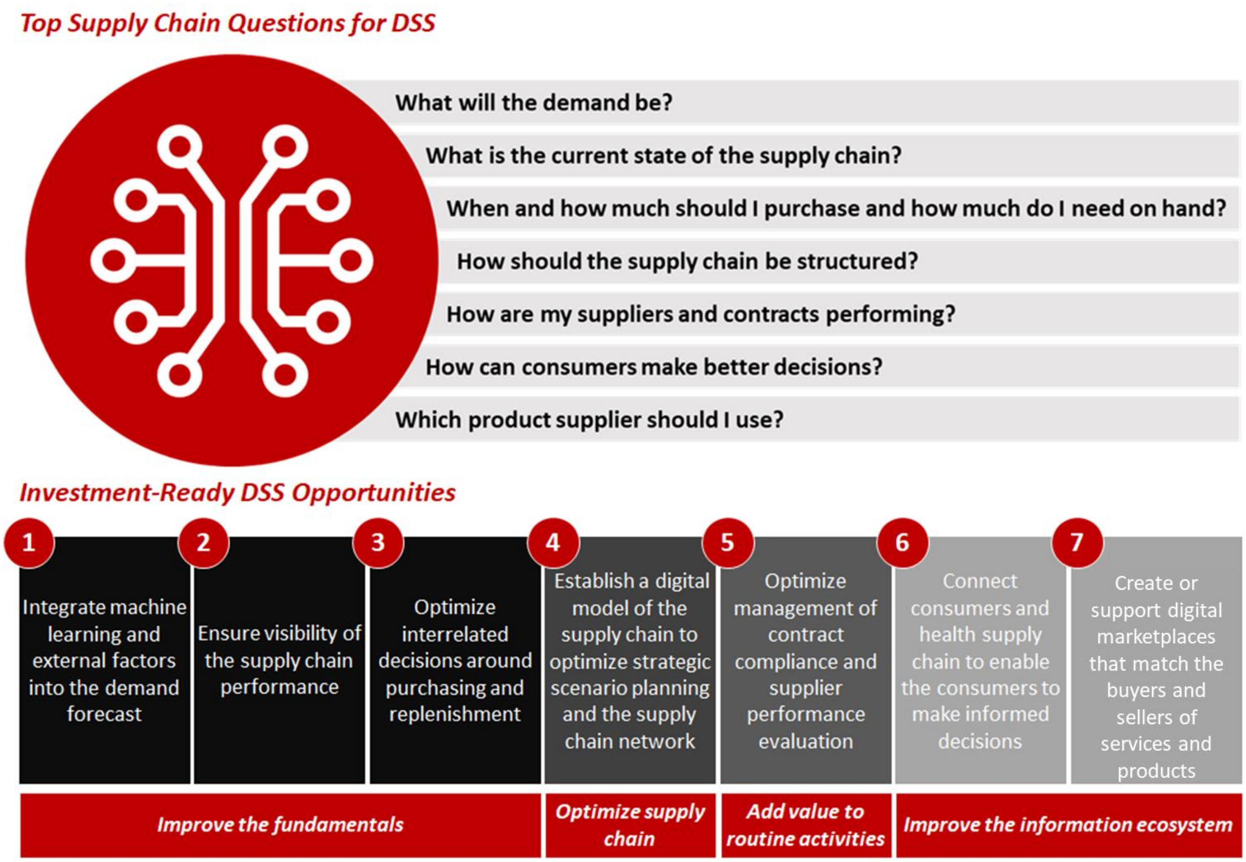


Figure 7: Transformative opportunities overview

What will the demand be?[31]

Among PHDC survey respondents, DSS that sense and predict are the focus of investment as more than a third of those who invested in an advanced DSS invested in this type of system. Demand forecasting, as a category of technology, is the most fundamental system in sensing and predicting the supply chain. It can be used at many levels of the supply chain for both purchasing and replenishment decisions.

In situations where there are long lead times and/or where demand is highly influenced by external factors, DSS that integrate machine learning into the demand forecast represent the greatest benefit for the lowest upfront cost. Some examples of commercial software providers offering demand forecasts based on machine learning and external factors outside PHDC are E2Open[32] and Relex.[33] Combinations of simple forecasts on periodic data provide an opportunity to make the supply chain more agile and responsive to exceptions with very little investment in the information ecosystem or infrastructure. This is particularly relevant for the one-year procurement cycles on which PHDC supply chains often operate. Advantages include:

- More accurate than traditional methods like averages/smoothing when predicting with long lead times.
- Can integrate explanatory factors such as changes in dispensing practices, the introduction of new medicines, demographic changes and weather.

Small scale bespoke DSS are particularly attractive for specific programs as they can be used where there is infrequent data and can be implemented on a laptop for a small number of SKUs using open source statistical packages like R and Python. These systems are already being used in some programs, including some malaria and HIV programs.

Machine learning-based DSS that can incorporate explanatory factors into the demand forecast will become increasingly important as health system data is better integrated into the supply chain. This can be used both to improve predictions and to explain demand patterns. Perhaps the best way to understand how this can be used is shown by the PHDC supply chain questions this technology can help to answer. Some examples (drawn from interviews) are:

"How can we understand how seasonality affects the demand?"[34]

"How can we predict the effect of a transfer between the current first-line anti-retroviral drug to the next first-line anti-retroviral drug?"[35]

"For a change from a 30-day to 90-day prescription, how will this change this will be reflected in your consumption curve? "[36]

"Can we pull data from different sources to predict the number of children that are expected to be vaccinated?"[37]

As the information on health factors such as births, child registers, services provided, and pathology and test results become available these new information sources and trends can be incorporated into intelligent demand planning. Non-health data such as local population size, demographics, distance to health facilities and weather/climate data also provide valuable input to the demand planning. Incorporating data from these external sources will increase the value of more advanced demand sensing systems, that automatically re-estimate demand based on changes in the underlying factors. Firms in the global pharmaceutical industry have seen improvements of 10-15% in forecast accuracy by employing machine learning in their demand forecasts.[38]

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[31] For more information on relevant demand DSS applications, see Appendix B: Applications of DSS
[32] E2Open 2019
[33] Relex 2019
[34] PATH, M. Morio, Interview
[35] Anonymous interview
[36] Anonymous interview
[37] Anonymous interview
[38] Accenture client experience

What is the current performance of the supply chain?[39]

There are already initiatives that improve visibility, for example VANs, and 55% of PHDC survey respondents who had implemented an advanced DSS indicate that the DSS help them to observe and describe their supply chain. These types of DSS incorporate dashboards reporting information from one or more systems on the last known performance of parts of the supply chain. Having this information is often a prerequisite for more advanced DSS and these represent an area for continued investment.

The information presented in dashboards needs to be situation-specific, tailored to the function and the level of the supply chain at which they operate. Often the same information is presented in different ways and different levels of aggregation to various users to suit their specific role. This needs to be directly linked with a decision that can be made based on the available data. Typical information included in dashboards are inventory levels in various units (i.e. quantities, buy price, sale price) and lead times and related KPIs (e.g. inventory turns, days of supply, projected available balance).

One of the key impacts of increased visibility is behavioral change. The supply chain relies on trust between actors, and where trust breaks down it can lead to unhelpful behaviors (e.g. hoarding). Allowing increased visibility in all directions – higher, lower and horizontally – can increase trust between actors, and help drive behavioral change to increase cooperation and improve performance.

Although dashboards and business intelligence platforms are not state-of-the-art, they still represent a key area for investment, particularly at lower levels of supply chain maturity. Several providers have implemented dashboards and business intelligence platforms in PHDC supply chains, for example OpenLMIS[40] , One Network[41] and Field Intelligence.[42] As supply chains become more mature and there are greater connections between nodes and integration of different systems, there are opportunities to improve end-to-end visibility. These systems track the movement of goods at each node and provide near real-time information on inventory levels across nodes. In practice we see logistics cost reductions of up to 5% due to better mode and carrier decisions, and reductions in the number of expedites and product detentions.[43]

How much should I purchase, when should I purchase it and how much do I need on hand?[44]

The complexity in making interrelated decisions around purchasing/replenishment and setting interrelated rules and thresholds like the safety stock, the economic order quantity and the resupply point make these good candidates for DSS. Some LMIS, such as OpenLMIS and One Network, include rules that help set multiple parameters at the same time. For simpler or less mature supply chains these provide a starting point in assisting decision-makers deal with complexity.

Supply chains with well-integrated information systems, defined rules and visibility over inventory and demand are in a position to take advantage of automatic procurement/replenishment DSS functions. These functions are often included in LMIS and there are examples in both public and private sector supply chains of both system-generated recommendations about purchase or replenishment/transport orders and systems that automate these processes completely. The majority of the investment is in the underlying data collection, sharing infrastructure and demand planning as systems with this DSS functionality are available off-the-shelf.

Bespoke and highly advanced DSS can help optimize these parameters while considering multiple relationships and constraints. These systems represent a significant investment, however, for large and complex supply chains these DSS provide support in dealing with problems that are beyond rules or simple calculations. In practice, using these

[39] For more information on relevant visibility DSS applications, see Appendix B: Applications of DSS
[40] OpenLMIS
[41] One Network 2019
[42] Field Intelligence 2019
[43] Accenture client experience
[44] For more information on relevant inventory and supply DSS applications, see Appendix B: Applications of DSS

DSS some firms in the global pharmaceutical industry have been able to maintain service levels while at the same time reducing inventory by up to 35%. [45]

How are my suppliers and contracts performing?[46]

DSS are beginning to be used to assist in procurement decisions. In one direction, DSS can assist in assessing supplier risk and help a decision-maker understand how many suppliers they should have and the level of scrutiny they need to put into supplier compliance. In another direction, DSS leverage natural language processing to extract the key terms from contracts. This is matched against actual supplier performance to ensure contract compliance. Examples of this type of solution used in global/developed country contexts include Seal Software[47] and RiskMethods[48]. These have so far only been implemented in non-PHDC, but given the importance of procurement decisions and the difficulty in checking contract compliance in many large and complex contracts, these types of DSS represent an emerging opportunity as the quality of procurement data improves.

How should the supply chain be structured?[49]

DSS that use a digital model of the supply chain for strategic scenario planning, or digital twin, present an opportunity to improve overall supply chain performance. These DSS require detailed data about the supply chain, but this data can largely be collected in a one-off process. They allow decision-makers to test scenarios such as changing the flow path of goods through the supply chain or removing nodes. Once built, the tools require limited data science or technical IT skills and scenarios can be run by the supply chain managers themselves.

Experience from network design and optimization projects include reduced distribution costs of 5% to 9%, as the supply chain is able to optimize the available capacity and resources.[50]

How can consumers make better decisions?[51]

There are opportunities to develop very simple DSS that better connect consumers and the health supply chain. These types of DSS primarily support the consumer to make better decisions. In the words of an interviewee, there is a need for DSS that "that allow individuals to take control of their care [and that take into account] their wishes and desires are on how to receive medicines."[52] A simple example of this type of DSS is the Electronic Regulatory Information System (eRIS) initiative to have QR codes on packaging in Ethiopia that allow consumers to verify the authenticity of the product with their mobile phone, to prevent the consumption of counterfeited products.[53]

Informing consumers about the availability of stock through something as simple as a web page or an "app that advises the patient on which pharmacy to go to"[54] is an easy way of enabling them to make better decisions about collecting or being administered medicines. Over time additional information like the estimated time of the next delivery can be iteratively added to these systems.

This also opens up an opportunity for the information to flow in both directions, from consumers back to supply chain managers by allowing consumers to notify of local stockouts. An existing example is the Stop Stockouts Project,[55] that report stock-outs in South Africa through their website. Allowing consumers to provide information about service levels provides an incentive for information to flow up the supply chain and the opportunity to verify that information using another

[45] Accenture client experience
[46] For more information on relevant supplier and contract performance DSS applications, see Appendix B: Applications of DSS
[47] Seal Software 2019
[48] Riskmethods 2019
[49] For more information on relevant network DSS applications, see Appendix B: Applications of DSS
[50] Accenture client experience
[51] For more information on relevant quality assurance DSS applications, see Appendix B: Applications of DSS
[52] Anonymous interview
[53] GS1 2019
[54] Anonymous interview
[55] Stop Stockouts 2019

source. Alternatively, social media monitoring is potentially another secondary source for information on supply chain events. Developing these types of DSS present an opportunity to better connect consumers with the health supply chain, with information flowing in both directions.

Which supplier should I use?[56]

One of the challenges faced in PHDC supply chains is the small number of options available to the supply chain manager. As neatly summed up in an interview, in PHDC supply chains:

"We need solutions that focus on how small markets can cooperate to solve their problems. We need to change the dynamic in order to boost cooperation across markets."[57]

Digital platforms that match buyers and sellers are a type of DSS that help aggregate data about suppliers and show the decisions makers the available options. At the last mile of the supply chain, there are some good examples of platforms that connect last-mile freight suppliers with customers. One example is Logistimo in India, Mozambique and Uganda, that uses a mobile platform to enable anybody with a registered vehicle to take on transportation jobs for rural freight.[58] We also find examples of delivery sharing platforms in non-PHDC, such as XPO Logistics, Uber, Deliveroo and Foodora.

There are complexities in procurement in public health contexts beyond those in many other markets, for example pharmaceutical regulations/standards and rules related to government procurement. However, there are already many consumer-facing examples of online pharmacies and there may be opportunities for the significant number of non-government actors, for non-pharmaceutical products, and even potentially many highly standardized off-patent medications.

These types of platforms also create an opportunity to enforce standardization, including contract terms, master data and product (across descriptions, dosage, pack size, etc.). Both standardization in contracting and in Master Data greatly simplifies risk analysis and provide data for other DSS.

Conclusion

There is a bright future for the development and integration of DSS into PHDC supply chains. The increased interest in using data is driving an increase in the integration of DSS functionality into many standard solutions, such as LMIS. The increasing availability of cloud technology and related software as a service and infrastructure as service offerings reduce the upfront infrastructure costs of DSS and provide much greater access to very advanced DSS. The rapid adoption of mobile phones makes it increasingly easy to capture data, particularly at the POS, as well as providing a convenient user interface for DSS, particularly for receiving alerts. These devices also have additional capabilities that may be able to be fed into the supply chain information ecosystem in the future, like fingerprint or facial recognition and the ability to take and send photos. These create opportunities as diverse as providing proof of delivery to checking the layout of remote warehouses.

DSS, end-to-end visibility, data sharing and interoperability are highly interlinked. The leading-edge opportunities in DSS rely on end-to-end visibility, which in turn rely on sharing data both up and down the supply chain, ideally from the consumer all the way to the manufacturer. Underpinning data sharing is the interoperability of data and systems. In practice this means consistent Master Data and the ability of the system to receive input and provide output to other systems. The ability to integrate health system data into the supply chain is a particularly important opportunity. Once these systems begin to be integrated technically, DSS can be used to support actors across the supply chain. These range from technically simple examples such as alerting warehouses to

[56] For more information on relevant platform DSS applications, see Appendix B: Applications of DSS

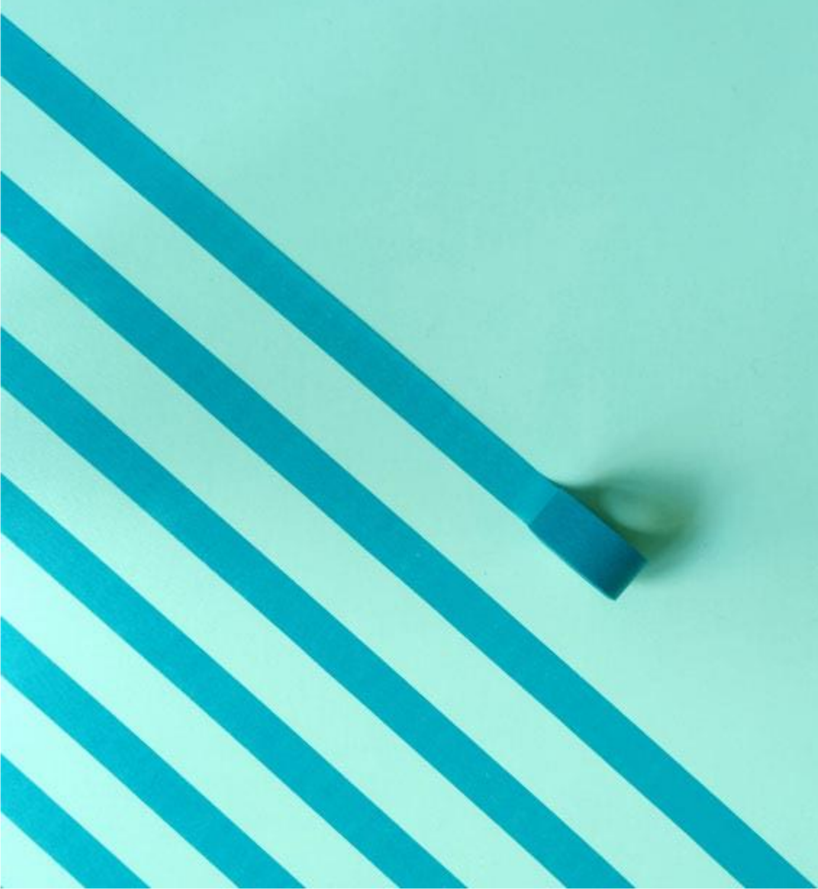
[57] Lightwell, S. Stremel, Interview

[58] Logistimo 2019

upcoming deliveries to more complex and integrated systems like supplier managed inventory. The greatest opportunities in DSS are to harness improvements in technology and data collection/sharing as part of the implementation.

DSS bring substantial benefits to supply chain performance. These systems are essential for visualizing the current situation, predicting future outcomes, connecting decision-makers with data sources across the supply chain and adjusting and optimizing supply chain functions. While the seven opportunities listed above represent only some of the areas in which DSS can be used to improve PHDC supply chains, they can provide the inspiration to explore the DSS that will have the most impact in a specific supply chain context.

5: Success and Guiding Principles



Every PHDC supply chain is different, and so the environment in which each DSS operates is unique. At the same time, many requirements and challenges are common across countries, health systems and supply chains, and so are many of the strategies for overcoming them. These have been distilled down to the set of guiding principle that conclude this chapter.

At a minimum, the enabling environment for DSS must include eight basic requirements in terms of the people, processes and technology:

People

1. *Motivation:* Stakeholders need to understand the benefits of using DSS in the supply chain.
2. *Capacity to understand technology and analytics*: Users need a basic understanding of how to navigate the tool, extract information and interpret it (e.g. how to read a graph).

Process

3. *Established supply chain processes* with documented roles and responsibilities.

Technology

4. *Electricity*, even if intermittent.
5. *Network connection* that can send and receive data, even if intermittent.
6. *User Interface* that decision-makers use to access the DSS, such as PCs, tablets, mobile phones.
7. *IT hardware* that can store data and process information as per system requirements.
8. *Data* relating to the supply chain function that the DSS supports.

This enabling environment represents the minimum requirements for DSS to function. However, to successfully implement DSS further lessons, or success factors, can be taken from both successful and unsuccessful past projects. These success factors exist in the union of people, processes and technology within PHDC supply chain.

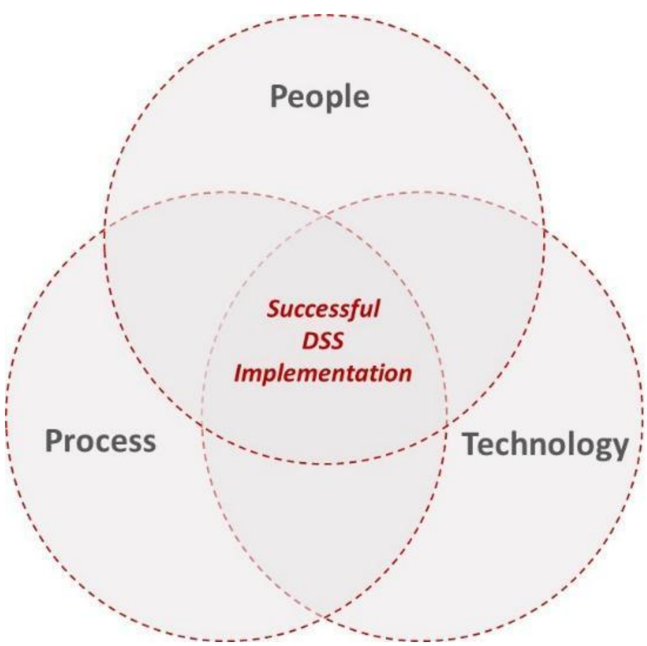


Figure 8: Critical Success Factors for DSS

People

Success begins with people, specifically aligning the interest of key stakeholders and having the skills to implement and use the systems. This is borne out by the survey results, where half of all PHDC respondents who have implemented advanced DSS identified either skills (40%) or aligning interest (15%) as key challenges.

Align interests

There are typically several actors involved in a public health DSS implementation, including leaders, government, implementing partners, donors, end-users and data collectors. These actors often have different interests and goals and it is vital to ensure that these stakeholders have an interest in its long-term success.

Leaders

In the words of one interviewee; "*All computer systems require behavior change and that needs leadership.*"[59] For leaders to support the process they need to understand the value of the DSS and support the change. Ideally, they should also have a direct stake as users of the DSS at a strategic level. The value of leadership to the success of DSS projects should not be underestimated: "*Even mediocre systems have succeeded thanks to good leadership.*"[60]

Government

Even in projects not directly carried out or initiated by government, country sponsorship, ownership of the project and political will are essential to drive the project forward. In order to achieve support from government, relevant governmental bodies need to be consulted in advance of the project and placed in the driver seat as the solution is developed and implemented.[61] Previous project experience has shown that in public sector supply chains, end-users do not trust the solution unless the government has endorsed it and therefore the DSS implementation will not be successful in the long-term.

End-users

Users need to see the value in using the DSS – where a tool is not ultimately seen as useful by its intended users there will not be long-term uptake. Users also need to retain ownership of the decision-making process. When users feel that they are losing control of decision-making, dilution of responsibility and user alienation occur.[62] Even where DSS incorporate advanced analytics or machine learning to guide decisions, the user should still be able to manually alter the decision and therefore be ultimately responsible for the outcome.

Data collectors

The workers who collect the underlying data are often forgotten when considering who needs to see the benefit of DSS. For a DSS to be successful, these stakeholders need to see the value in it, either through practical value in their job or through improvements they can see.

Data collection practices should not inadvertently create incentives to misreport or undertake "spiteful compliance" (e.g. skipping through fields or entering the same value in every field in the data collection system). In practical terms, this means data collection should require as little work as possible. The best way to ensure that data is collected accurately is to embed it in a process that assists the data collector in their other tasks. Point of sale/service data (POS) and barcode scanner data are both examples of data collected through a process that can ease the data collector's job.

These supply chain workers are responsible for or directly collect the data, and benefiting from DSS motivates them to collect high-quality data. Where bringing the data collector direct benefit is not possible, at the very least the benefits of the DSS need to be clearly demonstrated early on so that there is an incentive to collect good data to maintain the system in the long-run.

59 S. Rab, Interview
60 P. Dowling & E. Wilson, Interview
61 John Snow, 2017: p38
62 Paul, Jolley, Anthony, 2018:p64

Skills and human capital

Skills and human capital are important considerations in DSS design, selection and implementation. As discussed above, the long-term success of a DSS implementation rests on end-user uptake. To ensure this, the end-users will need to:

1. Appreciate the value of data in decision making;
2. understand the system to the extent that they trust the data and the outcomes of data analysis;
3. understand how to navigate the tool and extract information from it;
4. be able to interpret that information.

There is widespread recognition across industries that new skills are required as part of a supply chain DSS implementation. How much training is needed is connected to the end-user experience – the simpler the user experience, the lower the skill and learning barrier to uptake. As discussed below, this means minimizing the skills required and the time to learn the tool is a priority in the design of the user interface. Some PHDC supply chain organizations required as little as a few hours of training to skill up workers to use newly implemented DSS.

Ideally the DSS implementation will have access to trained supply chain professionals who have the skills to ensure good supply chain processes and advise on process improvement. This is connected to the need for good existing supply chain processes and supply chain process improvement discussed below.

Developing DSS that use techniques like optimization, machine learning and artificial intelligence require a team of data scientists,[63] in addition to the ICT skill set required to develop and maintain an IMS and other subject matter experts in health and supply chain. In the long term, the relationships estimated using most modeling and forecasting approaches change over time (concept drift) and are not robust to changes outside the factors considered by the model. How often data science skills will be needed depends on how quickly these relationships change and on how often the model is retrained.

Ideally specialist supply chain professionals, data scientists, ICT and health specialist will be available in-country. Experience suggests that projects that use local technical skills instead of relying on external support are more likely to be sustained in the long-run.[64] However, for very complex supply chain DSS even very large and successful companies in developed countries often outsource development and maintenance. Many of these specialist skill sets can be accessed remotely through fly-in-fly-out arrangements. Off-the-shelf solutions help minimize the need for these skills and even where a solution cannot be brought across directly from another context, many software providers offer modular DSS solutions as part of LMIS or IMS implementations.

Process

Existing processes

Before implementing DSS, underlying business processes need to be in place[65] and around 5% of survey respondents from PHDC supply chains listed introducing new processes as a challenge in their last advanced DSS implementation. Business processes outline the activities and roles and responsibilities of the actors. In the words of one interviewee:

"If you have a system that is working well, but say on paper, then it will do well. We need to move away from the idea that you can paper over the cracks using technology. You can´t automate something you can't describe."[66]

This helps the DSS implementation team assess the activities they need to automate, enhancements to make the solution fit the context and define roles in

[63] Generically describing professionals working with complex data using the scientific method, for example statisticians, econometricians, mathematicians and engineers employed in such tasks.
[64] Paul, Jolley, Anthony, 2018:p28
[65] John Snow, 2017: p38
[66] Anonymous interview

the system to align with the ownership in the physical supply chain. If the roles in the system are not properly matched with the actual responsibilities in the physical supply chain, there is a risk that accountability and ownership of tasks will be diluted.

There is considerable existing work on the process maturity, including work specific to the PHDC context, such as the Bill & Melinda Gates Foundation's Global Health Supply Chain Maturity Model[67] and USAID's Supply Chain Information Systems Maturity Reference Model.[68] Relevant supply chain key processes for each DSS application are listed in Appendix B: Applications of DSS.

Process improvement

As a best practice, it is important to improve existing supply chain processes as part of a DSS implementation. In the words of one interviewee; "*DSS are often brought in to support existing weak business processes. IT systems are not the magic bullet*".[69] The DSS implementation team will need to streamline the process with the support of new technology and tools. Improving underlying processes when implementing DSS is key to harnessing the full potential over the long term.

Technology

The context of PHDC supply chains makes technology an important consideration in DSS implementations and 15% of survey respondents in PHDC who have implemented advanced DSS found technology a key challenge. DSS are a type of computer system or subsystem and so their requirements are very similar to other IT projects. These general infrastructure considerations are briefly touched on below. The user experience and the underlying data are relatively more important to DSS than other IT projects and these topics are addressed as specific subsections.

Infrastructure

A modern laptop and open-source statistical software such as R or Python are the entry point for even very advanced DSS. Requirements increase with the amount of data, number of constraints, how fast the results are required/how often the model is run and the method used. Systems built on real-time data flows, systems that dynamically forecast or retrain and systems that use deep learning methods (for example image analysis or natural language processing) are likely to require more resources (i.e. dedicated servers or access to cloud computing).

As per other IT system implementations, the overall system requirements will depend on the processing and data storage models (e.g. in cloud, on-premises, edge computing), cybersecurity and data ownership laws and policies. However, some guiding principles are that network and storage requirements increase with the volume of data and the number of users. The processing requirements for web-based applications also increase with the number of users.

Improvements in public cloud availability and hybrid cloud solutions that mix on-premise, private and public cloud infrastructure represent alternatives to on-premise infrastructure. Combined software and infrastructure as-a-service offerings can also be used to reduce the initial costs and overcome challenges in finding the skills to maintain a DSS implementation. An indication of the system requirements of specific DSS can be found in Appendix B: Applications of DSS.

Like other IT systems deployed to developing counties, DSS may need to be robust to environments with intermittent electricity supply and network access. In developed countries, DSS are usually designed to be online continuously to synchronize data. However, several solutions in developing countries (e.g. OpenLMIS, Bileeta eLMIS[70], Field Intelligence[71]) can work offline and sync data when a network is available. How often the data from offline systems is updated needs to be considered as different DSS have different requirements in terms of how frequently the data is updated.

[67] BMGF 2016
[68] USAID 2018
[69] P. Dowling & E. Wilson, Interview
[70] Bileeta 2017
[71] Field Intelligence 2019

User Experience

To ensure adoption the user experience of the tool should be simple, yet powerful. Instead of providing the entire gamut of options to the user, the platform should focus on key information that each actor needs to make efficient supply chain decisions. This is highlighted by one interviewee recommendation *"to take the McDonalds approach"* and design the user interface with two questions in mind:

"How do you simplify the supply chain for the functions that have low retention? How can you work with simple visualizations to help them make decisions, without taking them through extensive training?"[72]

The key to successful implementation is to minimize the initial skills and human capital required to use the system and maximize its intuitiveness and the speed at which its full functionality can be learned and applied.

The user experience needs to be supported by the appropriate user-facing hardware. The variety of hardware used at different levels of the supply chain to cater to the different needs in South Africa provides a good example:[73]

- Facility and hospital: The electronic pharmaceutical management system is accessed through PCs, to manage inventory, purchase orders and issue/dispense medication. Smartphones/tablets enable health workers to capture stock levels as part of their working routine.
- Regional warehouses: Warehouse management systems are accessed through PCs to conduct transactional ordering, replenishment and right-sizing of inventory levels.
- Central warehouse/Department of Health: Performance dashboards monitor medicine availability and other KPIs at the national and the facility level are accessed through PCs to monitor and assess supply chain performance.

Because of the range of user interfaces across the supply chain the DSS should be designed to be versatile and work on the range of platforms found in the supply chain.[74]

Data

Master Data

Issues surrounding master data are some of the most fundamental challenges that affect PHDC supply chains. Master data provides the fundamental definitions used in an IMS. In a health supply chain, this commonly includes data on areas such as product attributes (for example type, dimensions, weight, dosage, pack size) and facility attributes (for example location, function, storage capacity). It is essential for both supply chain decisions and as a single source of truth for linking and harmonizing the data that underpin DSS.

Unlike other challenges related to data, the challenge in master data management (MDM) is not so much the collection of master data, as having it used and maintained by all parties in the supply chain once it has been collected. At the IMS level this means:

1. Establishing MDM & governance processes, including roles and responsibilities and leadership buy-in;
2. maintaining the integrity of master data provided by the data source across all internal systems;
3. adopting an existing standard, for example GS1.[75]

Supply chain data

Data use, trust, quality and collection form both virtuous and vicious cycles. Where data is not trusted, there is a reluctance to use it for decision making. If the data is not being used, there is little incentive to collect quality data. If quality data is not collected, then it is reasonable not to trust the data. If you cannot trust the data, there is little reason to collect it at all. This forms the vicious data cycle.

[72] Lightwell, S. Stremel, Interview
[73] Accenture South Africa, N. Nene

[74] The Principles for Digital Development provide further useful guidance on the user experience for it project in a development context.
[75] Alvarez 2018

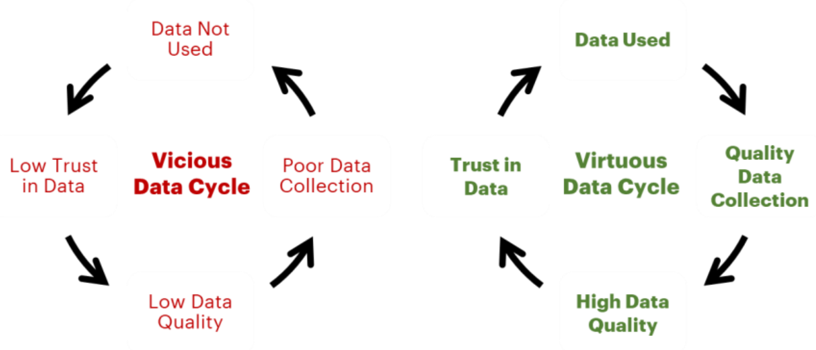


Figure 9: Virtuous and vicious data cycles

In the other direction, if data is being used in decision making, then there is a strong incentive to invest in data collection and ensure data quality. This reinforces trust in the data, which reinforces the extent to which decision-makers feel they can rely on it.

The best way to start the virtuous cycle is to begin using the data. This might seem counter-intuitive, but using the data is both the best way to show its value and an effective way of discovering its weaknesses. Data limitations make DSS implementation more difficult, but rather than reducing the utility of DSS, this interrelationship between data use and availability make DSS more valuable. Investment in improving data collection is very important, but they best support rather than proceed data use.

Both paper-based data collection and data collection as part of a reporting process have weaknesses that contribute to the vicious data cycle. The disadvantages of paper-based data collection include the duplication of effort in recording and then entering data and the long-time lag between collecting the data and being able to use it. This time lag means that the benefits of the data collection are not quickly demonstrated to either decision-makers or data collectors. As one interviewee put it:

"If lag time is high, like 4-6 months, you will not see the changes of the activities for 2 years, so it's difficult to drive change. If the lag time is smaller, you have the ability to have more impact as you can see the impact of the initiative more quickly and you have a greater chance for change."[76]

Because the benefits are not clear and there is considerable work in collecting and later entering the data, there is little incentive to undertake quality data collection and the results often lack accuracy and consistency.

Reporting processes also have disadvantages as a data collection method:

- The data collector often has no incentive to carry out high-quality data collection as they generally do not directly benefit from the data collection processes or data use.
- There is an incentive to undertake malicious compliance to make the job easier (i.e. entering the same value in every field).
- There can be incentives to manipulate the data to fake higher performance.
- Where the reporting shows poor results there is an incentive to undermine trust in the data.

These challenges are clearly not insurmountable, as reporting is used successfully in many spheres. But it does require good processes and accountability, which themselves can be challenges in PHDC supply chains.

One solution is to invest in tools which automatically collect data, for example from transactions, other processes or telematics. These require little additional effort in data collection and the results are available quickly so the value of the data collection can be demonstrated. Where the tools

[76] Lightwell, S. Stremel, Interview

make people's lives easier, they create an incentive to use the tool and improve data collection. The POS system that underpins data collection in Maisha Meds, shown below in Box 3, is a good example of how automated data collection can form the basis for DSS.

Box 3: Case study on Data Collection – Maisha Meds

Maisha Meds is a technology-enabled healthcare company providing digital tools to help pharmacies manage sales and inventory, and source quality medication in Kenya and Tanzania. The core product is a POS system that health facilities use to log every patient interaction in real-time. The data entry is logged as part of the regular routine of pharmacy staff, rather than a reporting exercise. The data is logged on tablets that require minimal upfront user training.

By logging POS data, managers get an overview of their gross margins and the overall profit and loss of their pharmacy. By combining gross margin data with decisions made in the past, managers can assess how they can improve their margins. The tool also provides an alert to restock when stock moves below a certain level and recommends the amount that should be reordered. This assists the decision-maker estimate and purchase the correct quantity and reduce the risk of stock-outs or expired stock.

The software is currently live in more than 150 pharmacies and clinics and expected to be rolled out to 350 pharmacies and clinics by the end of 2019.[77]

A complete data set of the entire supply chain is not needed to start conducting analysis. What is crucial is that the data that is used for decision making, whether part of a DSS or stand-alone, is accurate and reflects the reality of the physical supply chain. To successfully ensure that the data underlying the DSS is accurate, the data collection strategy should include processes to cross-check and validate key data and conclusions from various sources.

Secondary data sources are also an important source of data, particularly information collected by the broader public health system and other administrative processes, e.g. insurance claims. Noting that there can be administrative, legal and ethical challenges in accessing these types of data, it is important to consider how these sources can be incorporated into supply chain decision making.

[77] Maisha Meds 2018

Guiding Principles

There are many challenges in implementing DSS in PHDC supply chains. However, the number and variety of successful projects show that success is possible. While there is no guaranteed method for implementing DSS, the experience of past projects highlights many key areas of effort. To conclude this chapter, these lessons have been summarized into four guiding principles for DSS implementation in PHDC supply chains.

Figure 10: Guiding principles for selecting and implementing a DSS

Value Driven

A DSS should deliver value to as wide a range of stakeholders as possible, including patients, clinitions, users, data collectors, government and funders. The value needs to be:

- *Observable:* Stakeholders should directly observe the benefits on their everyday tasks to encourage use of the system.
- *End-to-end:* The DSS should ideally add value to both upstream and downstream actors across the supply chain to facilitate end-to-end cooperation and value creation.

Easy to use

The DSS should be easy to adopt for all stakeholders. This is achieved by:

- *Automating data collection:* Data should either be entered into a transactional Information System or be collected through automatic methods such as POS, Barcode, RFID or telematics.
- *User-friendly design:* The DSS should be designed to minimize the need for user training, with simple, intuitive and easy to navigate interfaces.
- *Appropriate training:* The requirements and scope for the user training need to be established in advance of the roll-outs. If end-users are difficult to reach, mitigation plans need to be developed (e.g. opportunities for remote training).

Design to share

The value of DSS is maximized if data and results can be shared across the supply chain, including public health information systems, to enhance end-to-end collaboration. In addition, synergies can be achieved across the global public health community by developing DSS tools that can be employed across the ecosystem. To achieve this, the following requirements need to be considered:

- *Strategic requirements:* The actors in the supply chain need to have a shared understanding of the necessity and the value of data sharing and a process for this activity needs to be established. The global public health community and their stakeholders should also have a shared understanding of the value of common architecture, algorithms and training data sets across the ecosystem. In addition to leveraging shared knowledge and expertise, the actors also benefit from lower cost as the cost of training a single model on a large data set can be significant and a barrier for adoption in LMICs.[78]

- *Technical requirements:* The technical requirements for data sharing should be a part of the evaluation of DSS solutions. The following requirments could be considerd:
  - Leverage the OpenHIE interoperability framework for a PHDC specific model architecture.[79]
  - Leverage algorithms that are documented under a publicly shareable licenses that allows further adaption and which can be deployed as an open-source stack of tools or cloud services that are not tied to a particular cloud service vendor provider.[80]
  - Make anonymized training data available under an open license.[81]

Plan for long term success

A plan for the long-term sustainment of success of the DSS needs to be established. The plan should include:

- *Long term commitment from the leadership:* Commitment from the leadership on the DSS transformation needs to be secured.
- *Long term strategy to retain skills:* The degree of dependency on the implementing partners/donors or other key individuals need to be assessed, and a transition plan needs to be established.
- *Plan for process improvement:* Given the function of the new system, the underlying processes should be improved to maximize the value of the technology.

[78] MIT Technology Review 2019
[79] OpenHIE 2019
[80] OpenHIE 2019
[81] Open Data Institute 2019, Open Data Commons Open Database License 2019

Call to action

DSS are inextricably linked to the systems that collect and share data. The greatest opportunities for DSS in improving PHDC supply chains are those opportunities that combine DSS with new data collection and sharing technologies. The best current examples are systems that use mobile phones or tablets to help data collectors in their daily jobs while collecting consumption data, cloud-based infrastructure to process and share data, and those same devices used in data collection to relay relevant information back to the end-user. This demonstrates the value of the data collection effort and creates an ecosystem that can support end-to-end applications of DSS from the end-user to the manufacturer. It is this combination of DSS, data collection and sharing technologies that allow a supply chain to leapfrog from low maturity to high maturity. These are not hypothetical systems – they already exist in both public and private PHDC supply chains.

While these represent the best opportunities for a single DSS implementation, the greatest impact of DSS on supply chains are structural. They are created by the accumulation of the smaller benefits and incremental changes in the way that data is used in decision-making. There is a temptation to focus on DSS as band-aid solutions to fix specific problems that affect specify supply chain functions. These are real benefits, but it is the fundamental changes in how a supply chain functions caused by implementing DSS across the supply chain that is truly transformative.

Technology alone can never overcome the challenges in PHDC supply chains. However, the effect of DSS in creating visibility has a broader impact on both people and processes in a supply chain. Visibility allows decision-makers to identify where problems begin. It creates trust by making decisions transparent. It breaks down silos. Using the data and showing the value of data collection motivates the collection of data in the first place and sharing identifies issues that would otherwise go unresolved. Visibility also enables and strengthens the impact of functional niche investments, such as investing in demand forecasting, supply and inventory management, contract and supplier performance and network optimization. The positive externalities of DSS technology on both people and processes in a supply chain accumulate to drive structural transformation.

More advanced DSS push the supply chain towards being truly proactive. Advanced systems can detect changes that will influence future demand and rerun demand forecasts in response, keeping the organization ahead of any changes. Data from these systems flow through to advanced supply planning and inventory optimization DSS which can automatically change the optimization strategy based on this new information. In turn this can be fed into all other supply chain systems allowing the supply chain to adapt before there is any negative impact on public health outcomes.

For supply chain professionals, the most important step in the DSS journey is to begin systematically using data in decision making. Small steps contribute to the cultural shift toward using data in decision making, trusting DSS type systems and create the incentive to collect good data. Each small implementation contributes to the shift from ad-hoc data collection and use, towards a proactive supply chain where issues are identified and dealt with before they can impact public health outcomes.

While supply chain professionals are central to driving DSS uptake, actors beyond the supply chain also have a key role:

Governments have a mandate to drive change and must shape the information ecosystem in a way that allows DSS uptake. This means fostering a culture of data sharing, promoting the interoperability of information systems and breaking down the barriers that create silos within public health.

Funders; whether donors, foundations or the private sector, can provide the capital and technical resources required to make targeted investments in DSS to drive iterative improvement in PHDC supply chains. When considering large investments, there are significant opportunities to combine investments in state-of-the-art data collection with state-of-the-art DSS. Funders also have the opportunity to contribute to the information ecosystem by creating incentives for interoperability, by making interoperability a specific condition of funding.

Software Development Organizations have an important role in working towards a high degree of DSS adoption by ensuring the interoperability of their systems and wherever possible make the systems and the training data open to allow a wide range of users to access the widest range of DSS. This means building systems that can share and be shared with, and including standards by design, for example across master data (e.g. GS1) and application protocols (e.g. HS7).

Implementing partners have a key role in managing the change that DSS imply and ensuring that the greatest benefit comes from the investment. DSS allow for different ways of working and there is also an important role for implementing partners in incorporating process improvement and organizational change in the implementation to make the most of the new capability.

Public health supply chains are critical systems to make medical products accessible, advancing global health outcomes and impact. DSS are just one technology that improve supply chains. However, they have the potential to have a transformative impact by lifting the burden from decision-makers and improving decisions by making it easy to incorporate data and analysis. DSS uptake means better-informed decision-makers, with more choices, and more options. They promote efficient, streamlined and asset-light supply chains that ensure good public health outcomes.

Conclusion

Workers across the public health supply chain are managing the constant risk that products that could save lives will not be available when and where they are needed. These decision-makers face the complex task of managing an ecosystem of organizations, people, technology, activities, information, and resources to minimize this risk. However, the inherent complexity means that it can be very difficult for decision-makers to take the right information into account in time to make an informed decision, or even identify where a decision needs to be made.

DSS are computer-based systems or subsystems specifically designed to help decision-making by incorporating the right information into the decision-making process and identifying where decisions need to be made. They help reduce the burden on decision-makers and overcome barriers to accessing data and analysis. By improving decisions they improve the efficiency and responsiveness of the supply chain and directly benefit public health outcomes. Each DSS has a direct effect on the supply chain function where it is implemented. Each additional implementation adds cumulative benefit and drives a broader change.

It is important to acknowledge the challenges across people, process and technology that organizations in PHDC face when implementing DSS projects. However, it is also clear that success is possible, as shown by the number and diversity of applications of DSS that already exist across demand planning, supply planning, inventory management, distribution management and quality assurance. While there is no single recipe for success, the Guiding Principles set out in Chapter 5 of this document capture the learnings of other projects in order to help projects succeed.

Where DSS will have the most impact is specific to a given supply chain; in particular to that supply chain´s maturity and the functions where improvement is a priority. However, based on common themes across interviewees, the survey and desktop research Chapter 4 outlined some promising applications of DSS for PHDC supply chains that can be divided into three categories:

Improve the fundamentals: 1) Integrate machine learning and external factors into the demand forecast. 2) Ensure visibility of the supply chain performance 3) Optimize interrelated decisions around purchasing and replenishment.

Optimize the structure of the supply chain: 4) Establish a digital model of the supply chain to optimize strategic scenario planning and the supply chain network.

Add value to other routine activities: 5) Optimize management of contract compliance and supplier performance evaluation.

Improve the information ecosystem: 6) Connect consumers and health supply chain to enable the consumers to make informed decisions. 7) Create or support digital marketplaces that match the buyers and sellers of services and products.

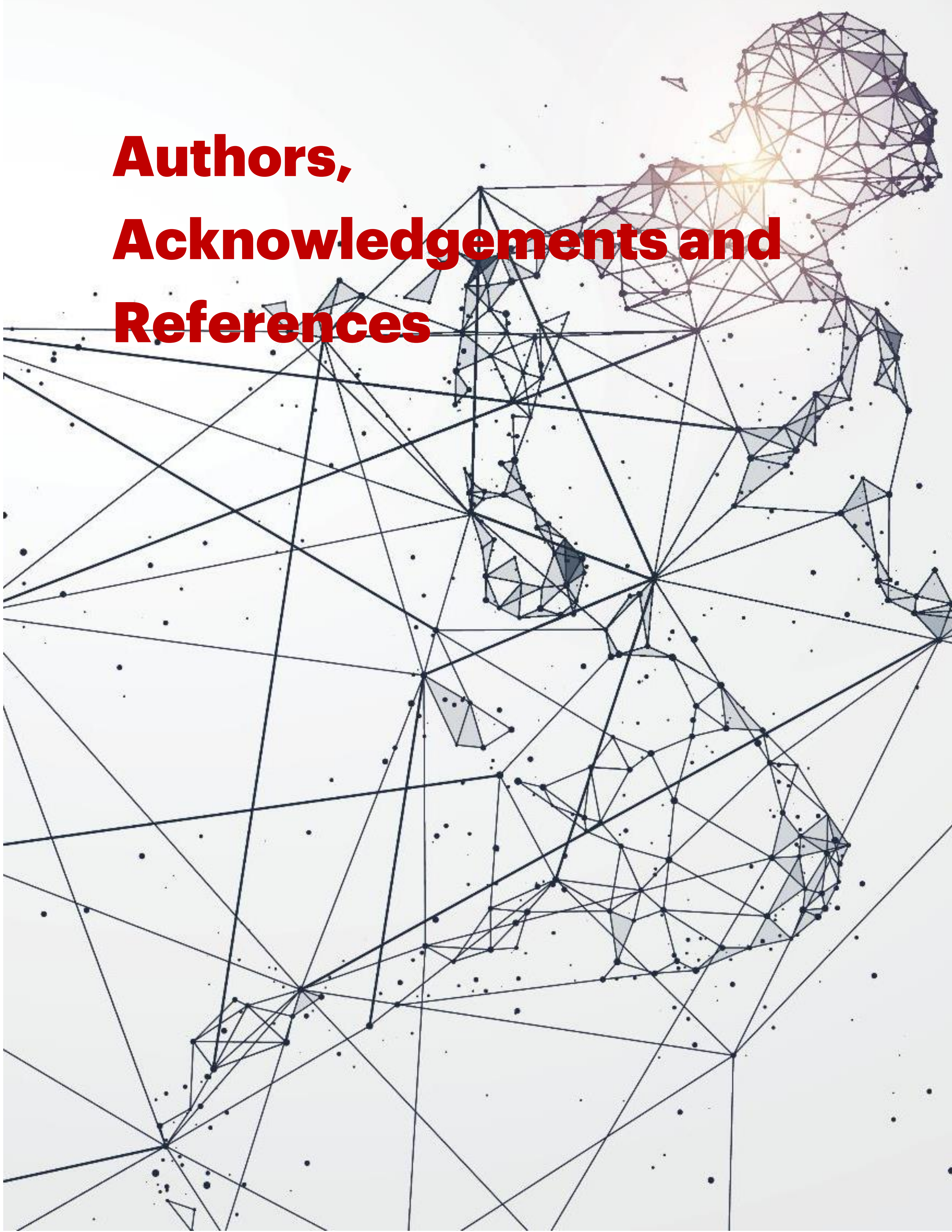
The digital marketplace requires significant collaboration between producers and suppliers, supply chain officials and regulatory authorities, but represent a significant opportunity to optimize the procurement process.

Because the greatest benefits are cumulative, DSS implementations are best thought of in terms of continuous improvement. While there are great opportunities to combine DSS, data collection and sharing technologies, it is also fine to start small. Each implementation reinforces using data as the basis of decision-making and creates trust in these types of systems. Each implementation improves the supply chain and gradually drives supply chain transformation.

These changes in the supply chain mean that small implementations may become redundant as the overall supply chain improves. This is a natural part of continuous improvement and is a positive change. However, it means that it is fundamentally important to create information ecosystems that enable new DSS functionality to be created and plugged-in. This is perhaps best thought of as an app-store approach to DSS functionality where software designers and implementing partners create solutions that connect to the underlying information ecosystem.

As the information ecosystem evolves the combined effect on how data is used by decision-makers fundamentally changes how supply chains operate. Improved visibility allows supply chains to become more agile and automated monitoring allows for exception management rather than scheduled processes. Efficiencies in supply and demand planning reduce the need to carry inventory, hollowing out the number and size of the physical storage required in the supply chain. The empowerment of decision-makers at each extreme of the supply chain leads to a trimming of the decision-making. The combined effect of DSS drives a transformation to more responsive, flatter and asset-light supply chains.

Authors, Acknowledgements and References



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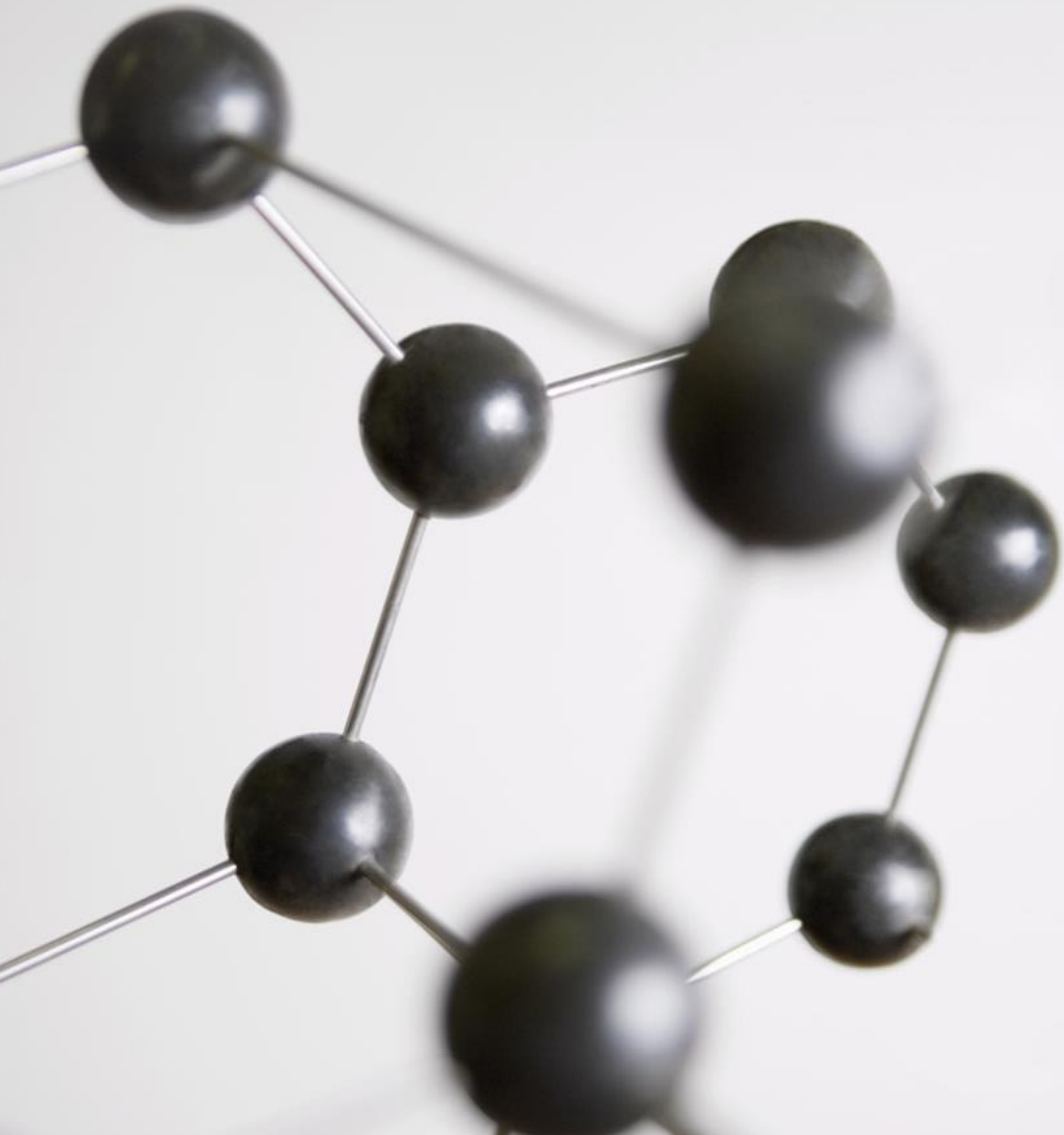
Appendices



Appendix A: Evaluation Framework

This structured evaluation framework outlines high-level considerations in assessing potential DSS applications in the context of a specific supply chain. The evaluation framework builds on the Prime Value Chain Approach,[82] which includes four-steps to identify current capabilities and prioritize opportunities.

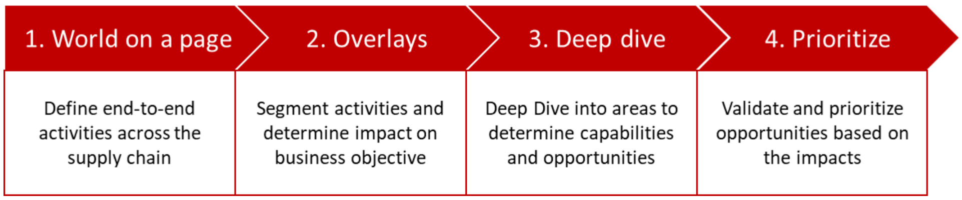


Figure 11: Evaluation framework overview

The key questions and the process flow of the evaluation framework are outlined in the figure below, followed by a description of each process.

Figure 12: Process flow

[82] Accenture 2014: p6 – 9

1. World on a page

First, define all end-to-end activities across the supply chain (from demand planning to distribution to the end patient). Second, identify activities that are critical in making supply chain decisions and the link to the rest of the activities.

The objective of the exercise is to identify the activities in the end-to-end supply chain that bring value to the decision-making process.

2. Overlays

When critical activities for supply chain decision making are mapped, the decision-making activities that should be prioritized can be identified. This is done by assessing how each individual activity impacts the key business objective of the organization (e.g. improving the availability of medicine). The activities are typically divided into high, medium and low impact categories.

The objective of the exercise is to identify the functional activities that have significant impacts on the business objective and that should be the focus of the DSS improvement process.

Activity	Impact
Demand planning	High
Supply planning	Low
Inventory management	Medium
Supplier management	Low
Distribution management	Medium
Quality Assurance	Low

Table 2: Illustrative example output from a simple overlay

3a. & b. Deep dive

Following the identification of activities that have a significant impact on the business objective, conduct a deep dive that assesses the current maturity of each activity and the strategic goals for those specific activities.

PHDC supply chain capability maturity can be assessed through several existing maturity assessments. Tools specific to the PHDC context include the Bill & Melinda Gates Foundation's Global Health Supply Chain Maturity Model[83] and USAID's Supply Chain Information Systems Maturity Reference Model.[84] Key elements required to implement a DSS at a given maturity level are listed in Table 3 and a summary of the USAID's Supply Chain Information Systems Maturity Reference Model can be found in Appendix D: Summary of Supply Chain Information Systems Maturity Across Levels and Functions.

[83] BMGF 2016
[84] USAID 2018

Level	Maturity description
Level 0	• No defined supply chain processes or roles • Data is stored in paper-based/offline systems
Level 1	• Defined supply chain processes and roles • Users and leaders understand the benefit of using data in decision- making • Data is captured through manual reporting and planning is carried out through ad-hoc processes
Level 2	• Users and leaders understand the benefits of automated data capture and processing • Automated data capture through a transactional system and automated data processing
Level 3	• Defined supply chain data sharing processes • Users and leaders understand the benefits of data sharing • Interoperability layer enables the use and transfer of data across systems (e.g. cross-functions, cross-regional and external data)
Level 4	• Data is captured in near real-time and new systems can be easily integrated into the information management ecosystem

Table 3: Summary of key DSS relevant supply chain

Following the assessment of the maturity level, strategic goals need to be defined. Examples of strategic goals are included in Table 4 for quick reference. However, these strategic goals should be tailored to each specific critical functional activity that has been identified (e.g. specific strategic goals for demand planning).

Functions	Level 1	Level 2	Level 3	Level 4
Demand planning	I want to know what my demand will be	I want to perform automated demand calculations	I want to automatically integrate demand data with other processes	I want my demand forecasts updated automatically based on real-time data and external variables
Supply planning	I want to know what supplies to order and when to order them	I want to automate ordering recommendations	I want to automatically integrate supply data with other processes	I want my ordering recommendations to be updated automatically based on real-time data on demand and inventory
Inventory mgmt.	I want to know current inventory levels	I want to perform automated inventory calculations I want to optimize inventory levels	I want to automatically integrate inventory data with other downstream and upstream processes	I want my inventory calculations updated automatically based on real-time demand and supply data
Supplier mgmt.	I want to know if my suppliers are meeting their contractual obligations and if they are underperforming	I want to perform automated supplier and contract KPIs calculations	I want to automatically pull data from relevant IT-systems to assess supplier performance	I want my supplier assessments updated automatically based on real-time data
Warehouse mgmt.	I want to know when incoming stock will arrive I want to know what to ship next	I want automated recommendations on warehouse management (e.g. where to put a shipment)	I want to automatically integrate warehouse data with other downstream and upstream processes	I want warehouse management tasks automatically updated based on real-time shipment data
Distribution mgmt.	I want to know where in the supply chain goods are I want to know how to structure my network	I want to automatically calculate the best route and predict delays	I want to automatically integrate distribution data with other processes	I want to automatically update routes and ETA based on real-time data (incl. external variables)
Quality Assurance		I want to automatically monitor the temperature in a specific warehouse/facility	I want to be able to back-trace the origin of the medication	I want to integrate temperature /equipment monitoring to automatically adjust operations

Table 4: Summary of key DSS strategic priorities across maturity levels

The objective of the exercise is to identify opportunities for key functional decision-making activities that have a significant impact on the business objective.

4a. Identification and prioritization of DSS applications

When opportunities have been identified, relevant DSS applications can be assessed. The key DSS applications exist in the intersection of what can be achieved, given the current information system maturity and the strategic goals. Where there are no relevant opportunities this indicates that prior investment is needed in improving supply chain information system maturity.

When relevant DSS applications are identified, a prioritization is made based on the value and effort in implementation. The opportunities are typically divided into the following categories:

- Rapid Improvement, involving quick wins typically addressing a limited supply chain function area
- Cross Functional Opportunities, involving collaboration across the supply chain functions
- Complex Opportunities, involving structural changes and strong leadership support for transformation

The division typically creates the basis for a roadmap detailing the implementation activities.

Table 5 summarizes the DSS applications for each maturity level (level 1 to level 4) for all functions. If you have a maturity level 0, you will need to invest in the enabling environment before investing in DSS. If there are no relevant opportunities at or below current maturity, consider opportunities requiring higher maturity. These can be accessed through first investing in supply chain information system maturity. Further information on each application of DSS can be found in Appendix B: Applications of DSS or through following the hyperlinks included in the table.

	Level 1	Level 2	Level 3	Level 4
Demand planning	Manual averages/smoothing/ML: • Demand planning Manual RB/model competition: • Demand forecast selection Manual RB: • Product grouping (segmentation) Manual statistical analysis: • Level of forecast • Forecast accuracy	Automated ML: • Demand planning Clustering: • Product grouping (segmentation)	Automated ML incorporating external data: • Demand planning	Automated and real time ML: • Demand sensing
Supply planning	Manual RB: • Lead time • Order quantity • Economic order quantity • Safety stock target	Automated RB/statistical analysis/ML: • Inventory optimization • Labor and transport capacity	Automated & integrated ML: • Advanced inventory optimization • Advanced price modeling	

	• Re-order point Manual RB/statistical analysis/ML: • Fast- and slow-moving inventory			
Inventory management	Visibility: • Dashboards/Business Intelligence Manual RB: • Forecasted inventory • Demand prioritization	Automated RB: • Forecasted inventory • Demand prioritization	Reinforcement learning: • Demand prioritization	
Supplier management	Manual RB: • Performance monitoring	Automated RB: • Performance monitoring	Automated & integrated ML: • Advanced supplier performance monitoring • Contract performance monitoring	
Warehouse management	Manual RB: • Warehouse management orders	Automated RB: • Warehouse management optimization	Automated & integrated statistical algorithms: • Warehouse management adjusted to other events	
Distribution management	Manual RB: • Network analysis Manual statistical algorithms/ML: • Route planning	Automated statistical algorithms: • Flow path optimization Automated ML: • Route planning	Automated & integrated ML: • ETA and delay prediction	
Quality Assurance		• Non-integrated RB/statistical analysis of telematic	• Automatic product tracking of end-to-end supply chain	• RB/statistical analysis of telematics • Predictive maintenance

Table 5: DSS applications

4b. What do I need to consider when selecting the DSS solution?

Once the DSS applications with the greatest benefit have been identified, the available solutions need to be assessed against key implementation criteria. In addition, the functionalities of the individual DSS solutions need to be assessed separately. Eight suggested selection criteria are listed below:

The DSS provides the right information:

- Does the information create more options?
- Does the information create more choices?
- Does the information create additional decision-makers?

The DSS provides the right information to the right people:

- Can the decision-maker make more informed decisions based on the information?
- Can the decision-makers change their choice based on the information?
- Can the decision-maker do something that they could not do before?

The DSS is robust to the environment:

- Is there a reliable electricity connection or is the DSS robust to intermittent power?
- Is there a reliable network connection or is the DSS robust to intermittent connectivity?

The ongoing costs of the DSS can be met, including:

- Mobile data and network costs
- User interfaces and system requirements
- Analytics model maintenance
- Cloud processing and storage
- Licensing costs/Service costs

The DSS can scale as it demonstrates success and there is wider uptake:

- Can the system scale to accommodate an increase in the size and volume of data flow?
- Can the system scale to accommodate an increase in the frequency the algorithm is run/trained? For example:
    - a shorter lead time;
    - an increased number of users where the DSS is run for each user.

The DSS is designed to share:

- Does the DSS receive inputs and provide outputs to other systems?
- Does the system use/support common master data (preferably a standard, i.e. GS1)?
- Does the system use/support common consistent application protocols (preferably a standard, i.e. HL7)?

The DSS is user-friendly:

- Does the DSS provide the right information to the right decision-makers?
- Does the DSS support alerts and proactive notification to distributed decision-makers?
- Is the DSS appropriately targeted to the capabilities and competencies of the end users?
    - Does the DSS provide simple scorecards and dashboards providing “at-a-glance” information?
    - Does the DSS provide information in a graphical or easily interpretable manner?
- Does the DSS support customized reports?
- Does the DSS support role specific profiles or customizable profiles?

Long term support is available from the vendor or community:

- Will the vendor or open source community have a long-term presence?
- Will the vendor or open source community continue to invest?
- Does the DSS include ongoing customer/community support?
- Are subject matter experts, i.e. Data Scientists, IT professionals and supply chain experts available?

Conclusion

The prime value chain analysis provides a structured framework for evaluating relevant DSS applications. The approach can be tailored to each supply chain context, however, it is recommended to follow the outlined steps in order to maximize the value of your DSS investments.

Appendix B: Applications of DSS

The section provides a high-level technical overview of those existing DSS that are most relevant in the PHDC context, rather than an exhaustive list of all existing DSS.

Applications are ordered under supply chain functions and the key questions related to that function. Where multiple applications have been included they are listed from least to most complex. Technical details are provided at the beginning of each section, and where these technical details are significantly different for different applications within a section, the headings have been repeated and additional technical information included. Where they do not significantly differ the nuances in technical requirements are provided in the notes.

Demand planning

In order to purchase the correct amount of goods or quantify the goods required at a given location, the manager needs to have a prediction of future demand. DSS use forecasting – making a prediction about the future based on the past – to assist in many aspects of demanding planning. Technically, historical demand is always unknown, and so demand forecasts use proxies for historical demand, typically consumption data or stock depletion data. The most important consideration is to have data that represents the underlying demand.

The uses of demand forecasts include quantifying the goods required at various levels of the supply chain, from the national level right down to the facility level, forming the basis of both purchasing and replenishment decisions. A prediction of future demand is also integral to all other supply chain planning decisions, and the results of forecasts are used as inputs into other DSS, particularly in supply planning and inventory management.

Choosing the correct method of forecasting can be complex and some of the considerations include:

- What do we want to predict?
- At what level of the supply chain are we forecasting?
- What is the time horizon (a forecast is related to the lead time of the products and the data collection period)?
- Is demand stable, seasonal or very volatile?
- Is demand affected by external factors?
- Is demand easy to predict or difficult to predict?
- How quickly can the supply chain respond (the more responsive the supply chain, the more useful are short term and highly reactive forecasts)?

Along with DSS that assist in understanding what demand will be, there are also DSS that support the decision-maker in choosing the correct forecasting method. The following section first outlines methods for demand planning from the simplest to the most complex under the key question "What will my demand be?". It then sets out some of the other tools that assist decision-makers in choosing the correct forecasting method under the appropriate key question.

What will my demand be?

DSS Technology – Averages/smoothing

Overview: The simplest method of predicting future demand is to use a moving average or smoothing technique. They have a number of advantages, including their relative simplicity in implementation and the low data and system requirements. They work best over short-time horizons (weeks) and where there is a high volume of data, as the forecast is easy to rerun.

Current use: There are many examples of this type of forecasting in PHDC supply chains, often based on data on stock depletion from stock-on-hand data in the physical inventory (e.g. Delivery Team Topping Up System) which are manually added to an electronic system periodically.[85] The forecast is based on manual calculations in a spreadsheet or any other similar system to identify future demand.

These types of forecasts are calculated automatically in many LMIS used in PHDC supply chains. The decision-maker verifies the forecast and decides on future demand based on the forecast.

Maturity Level 1: [86] An organization needs to have consumption or inventory data stored in an electronic information system.

Key processes:

- Develop demand plan
    - Collect data that represents the underlying demand (e.g. consumption data).
    - Generate forecast: Select method and execute.
- Publish demand plan
    - Consensus approval of demand plan.

Skills:

- Users
    - Strategic leaders: Translate the output of the forecast into impact on regional/national forecast.
    - Supply chain managers: Interpretation of the results of the forecast.
    - Supply chain planners/analysts: Ensure accurate data input and run the models. Basic knowledge of the logic of the model.
    - Supply chain operators: Accurate data entry (when using inventory as a demand proxy).
    - Clinical staff: Accurate data entry (when using consumption data as a demand proxy).
- Data scientists: In some cases the selection of the averaging/smoothing method requires a data scientist.

Data: How much, when, and metadata (including what, the periodicity, the unit of measurement).

System requirements: Low (Can be designed using formulas in a spreadsheet if necessary).

Methods: The choice of method largely depends on whether there is a clear trend in the historical demand, for example a steady increase or decline and whether the data is seasonal. Illustrative methods are listed against each combination of these two factors.

- No trend or seasonality: Simple average, Simple moving averages, Simple exponential smoothing, ARIMA.
- Trend with no seasonality: Double moving average, Double exponential smoothing, Holt exponential smoothing, Time series decomposition.
- Seasonality and no trend: Hold-Winter multiplicative method without smoothing, Time series decomposition, Seasonal ARIMA.
- Trend and seasonality: Winter exponential smoothing, Time series decomposition.

The most complex averaging/smoothing algorithms use more than one method to provide improved performance over different sections of the time horizon.

[85] USAID 2014
[86] See Appendix A: Evaluation Framework for more information on the maturity levels

DSS Technology: Machine learning

Overview: Demand forecasting using supervised machine learning represents one of the clearest opportunities to improve demand planning, even where data is captured with a significant time lag as they are able to make accurate predictions over relatively long-time horizons.

Current use: Some simple machine learning methods are included in commercial LMIS platforms and these systems are frequently used in the private sector. For example, the retail industry uses the method frequently to predict the demand for fruit and vegetables, where factors such as weather are included in the calculations.

There are also examples of demand forecasting calculation incorporating both internal and external factors in PHDC supply chains using linear regression.

Maturity Level 1: An organization needs to have consumption or inventory data stored in an electronic information system.

Processes: As described under Averages/smoothing.

Skills:

- The users require the same skills as described in the averages/smoothing technology.
- Data scientists: Selection and evaluation and ongoing maintenance of the model (at implementation and periodically depending on the stability of the underlying relationships (monitoring at least biannually)).

Data:

- Require the same data as described in the averages/smoothing technology.
- Additional data required: Explanatory factors (User: promotions, marketing, new products). External factors: Seasonal factors (month, holidays/festivals), weather, economic factors, demographic factors.

System requirements: From Low to Medium, depending on the application. DSS based on these methods can be programmed in statistical software like R or Python and basic machine learning is included in some LMIS. Small applications can run on a laptop (<10,000 observations). For large numbers of SKUs (as a rule of thumb, over 500) or observations (as a rule of thumb, over 100,000), the system requires at least a server.

Methods: The methods range from general linear regression models to non-linear regression to random forest-based approaches, depending on the number of goods (SKUs). Single SKU prediction can use general linear regression models or non-linear regression, while random forest-based approaches (i.e. XGBoost) are used to estimate multiple SKUs at the same time.

DSS Technology: Automatic machine learning

Overview: Automatic machine learning allows the DSS to adjust the forecast without human oversight. This allows the system to be much more flexible, to respond quickly to changing relationships in the data and to use information from very large volumes of data, for example near real-time scanner or POS data. They are also able to automate many of the decisions required in selecting a forecasting method.

Current use: Automatic machine learning is used in some larger non-PHDC supply chains.

Maturity Level 2 - 3: An organization needs to have automated consumption or inventory data collection with storage in an electronic information system (level 2). If external data are used an interoperability layer is required (level 3).

Processes: As described under Averages/smoothing.

Skills:

- The users require the same skills as described in the averages/smoothing technology.
- Data scientists: Selection and evaluation and ongoing maintenance of the model (monitoring at least monthly)

Data: Requires similar data to machine learning, but is able to use a much larger volume and complexity of data.

System requirements: Low to High. The requirements are related to the amount of data – with small amounts of data - these systems can in theory be run on a laptop (e.g. 10,000 data points for a monthly forecast). However, as the advantages of these systems are the ability to use large amounts of complex data, they are typically implemented in a cloud as they require a large amount of processing power when running the models.

Methods: The system chooses the machine learning approach based on a model competition against historical data. The system chooses the best model based on criteria, including both statistical measures of accuracy and bias.

The most advanced systems also include a step that automatically groups goods (SKUs) based on their shared attributes. These are described in more detail below under the heading "What kind of demand forecast do I need".

DSS Technology: Demand sensing

Overview: Demand sensing is the most advanced forecasting method and describes systems where the forecast is adjusted (´reacts´) in near real-time to changes in actual consumption patterns (registered through POS systems). These systems are appropriate where the supply chain is highly responsive, as the forecast is able to signal short term changes in predicted demand (i.e. usually within the next week, but potentially daily).

Current use: Demand sensing is still in the progress of being adopted by non-PHDC supply chains.

Maturity Level 4: Demand sensing requires access to near real-time data from multiple information systems, i.e. transactional (POS or barcode) or telematics.

Processes: As described under Averages/smoothing, however, the final forecast consensus process step is redundant.

Skills:

- The users require the same skills as described in the averages/smoothing technology.
- Data scientists: Selection and evaluation and ongoing maintenance of the model (monitoring and exception management).

Data: Used when there is access to very up to date data, for example near real-time POS data.

System requirements: Usually implemented on cloud, as these systems require a large amount of processing power at very specific times to re-run the forecast.

Method: The intuition behind this type of system is that where any key attributes change, the system re-runs the forecast, including model selection, taking into account the changes in the factors. The types of data monitored include internal factors, for example large increases or decreases in the flow of POS data, or external factors, for example data collected through social media or weather data.

Other Demand planning DSS

There are a number of DSS that assist the decision-maker to navigate the complexity of choosing a forecasting method, conducting some of the underlying processes, such as grouping products by like features (product segmentation) or evaluating the demand forecast́ s performance.

What type of demand forecast do I need?

These DSS assist the decision-maker to choose the correct method for demand forecasting. They are often included in commercial LMIS systems, where they help the user choose between averaging/smoothing approaches. DSS that use automatic machine learning automate the process of model selection.

DSS Technology: Rule-based techniques are often used to help identify slow-moving products, identify products whose demand patterns have changed and classify products as having a trend or being influenced by seasonal factors. Based on these rules forecasting methods are suggested or automatically implemented by the DSS.

DSS Technology: Model Competition: More advanced techniques involve running a model competition, where multiple models are tested and the best is selected (according to statistical analysis of factors and measures of fit and bias). In machine learning models this process is carried out by data scientists, while in automatic machine learning, this process is automated.

How should I group my products?

DSS Technology: Complementarity: Rule-based approaches are used to identify the relationship between complementary products (i.e. attach rates). These are common ratios based on the predicted demand for complementary products and aftermarket services associated with a primary product.

DSS Technology: Segmentation: There are also rule-based and statistical techniques to conduct segmentation (group products based on like attributes), for example demand variability, volume, profit or revenue/cost share. Both of these are commonly included in commercial LMIS.

DSS Technology: Clustering is used in more advanced systems based on unsupervised machine learning. This method has the advantage of being able to create more clusters than simple statistical approaches as it can look at non-correlated variables. These techniques are not typically included in LMIS systems and usually built into bespoke systems that have been customized to a particular supply chain.

At what level should I forecast demand?

DSS Technology: Aggregation: LMIS typically include an option to view the demand forecast at multiple levels of the supply chain (e.g. CMS, Regional Distribution Centre, Facility). This can assist planners in understanding at what level it is best to forecast demand.

DSS Technology: Hierarchy analysis: Statistical techniques can also be applied to undertake a hierarchical analysis by analyzing factors such as the volatility or intermittency at each level. The best level at which to forecast demand is chosen through back testing (tested against historical data). These techniques are not typically included in LMIS and are part of highly customized and bespoke DSS.

How do I measure the accuracy of the forecast?

There are a variety of calculations and statistical techniques that assist in understanding the accuracy of a demand forecast. All DSS that include an underlying demand forecast should include measures of forecast accuracy.

Simple measures of accuracy include:

- Average, maximum, minimum forecast error

- Standard deviation
- Tracking signal = sum of forecasting errors/mean absolute deviation
- Bias = sum of deviations (actual – forecast)/number of observations

Machine learning models also typically include estimates such as the standard error, confidence intervals, and goodness of fit statistics (for example absolute measures like R^2, sudo-R^2 and relative measures like AIC or BIC).

Measures of accuracy are difficult to interpret without specific training in statistics. Visual representations of forecast accuracy and bias are more easily interpreted and go some way to assisting decision-makers. Ultimately, however, given the fundamental role of demand forecast, all supply chains require some specialists who are able to evaluate forecast accuracy and bias.

Supply planning

Supply planning is the supply chain function that organizes the fulfillment of the requirements identified in demand planning. The following section addresses these DSS applications.

When should I purchase, how much should I purchase and how much inventory should I have?

DSS Technology: Individual calculations

Overview: The simplest DSS provide users assistance in each supply planning question separately and are included in many commercial LMIS.

Current use:

The most basic DSS advise the decision-maker on the number of supplies that should be ordered and when they should be ordered. There are several examples of this practice in PHDC supply chains, where consumption data and inventory data are available in an electronic information system. The consumption and inventory data help the decision-maker manually determine the supplies that should be procured (e.g. PipeLine Software).[87] For mature PHDC supply chains, the decision-maker can also make an order to a supplier with a Long-Term Agreement/framework order directly through the system (e.g. Entuition Vesta – eLMIS Bileeta).[88] Common functions include:

Lead time, or the time between order and delivery, can be calculated using rules and summarized by a single statistic, such as an average, based on historical lead times. More advanced systems fit a probability distribution to the lead time to provide a better estimate of variability that can be used by other more advanced DSS.

Order Quantity is calculated based on forecast demand and the lead time, typically using rules. The output is used as a recommendation for the decision-maker or in more advanced systems, to automatically purchase or order goods.

Economic order quantity is similar to order quantity calculation but also takes into account the relationship between costs (product cost, transport costs, warehousing costs) to identify the best purchase or order quantity.

Safety Stock Target setting is based on rules related to the service level targets. More advanced systems also take into account demand uncertainty, lead-time variability, review order/purchase frequencies and batch order quantities in recommending a safety stock target.

[87] John Snow 2019
[88] Bileeta 2017

Re-order point setting is calculated based on rules that take into account the estimated lead time, order quantity/economic order quantity and safety stock target.

Maturity Level 1: An organization needs to have supply data stored in an electronic information system.

Processes:

- Develop supply plan
    - Acknowledge receipt of demand plan.
    - Assess supply plan input: Demand plan and stock on hand.
- Convert Planned Orders into Purchase Requisitions
- Develop inventory plan
    - Review inventory planning data.
    - Calculate revised safety stock.
    - Final inventory consensus and publishing.

Skills:

- Users
    - Strategic leaders: Translate the output of the supply plan into impact on regional/national supply plan and into the procurement plan.
    - Supply chain managers: Interpretation of results of the supply plan.
    - Supply chain planners/analysts: Ensure accurate data is input and run the models. Basic knowledge of the logic of the model.
    - Supply chain operators: Accurate data entry.
    - Clinical staff: N/A.
- Data scientists: Required to design, evaluate and maintain more advanced solutions as noted in each application of DSS.

Data: What, the location, a demand forecast; historical lead times, and the minimum order quantity.

System requirements: Low.

Methods: Rule-based.

DSS Technology: Inventory Optimization using interrelated rules

Overview: More advanced DSS approach all of the questions simultaneously to conduct Inventory Optimization using interrelated rules and are also included in some more advanced LMIS.

Current use: Outside PHDC supply chains, advanced DSS tools advise the decision-maker on whether specific deliveries should be rescheduled based on anticipated consumption. These methods are used across a wide range of private sector industries, such as retail, manufacturing and raw material production.

DSS also advise the decision-maker on whether any immediate reallocation of inventory across the network is required to meet forecasted demand.[89] Private sector companies are typically investing in these methods at the same time as they invest in automated control of inventory. These tools are frequently used by industries that have high inventory levels and/or a large number of stock keeping units (SKUs), such as retailers.

Maturity Level 2: An organization needs to have access to transactional inventory data.

[89] Bleda et. al, 2014: p7

Process: As described under Individual calculations, however, inventory parameters are calculated jointly by DSS. The process still requires human verification of the results.

Skills:

- As described in the Individual calculation section. In addition, the supply planners/analyst need a basic understanding of the different parameters and how they impact the inventory policy.
- Data scientists: Not usually required in the supply chain.

Data: As described in the Individual calculation section.

System requirements: Medium, an underlying electronic system is required.

Method: Inventory optimization is the process of setting the Safety Stock Target, Reorder point and Economic order quantity simultaneously, given the estimated lead time and forecast variability, and target service level. At its most basic this can be set using interrelated rules or by running a limited number of scenarios while manually varying parameters. This method is sometimes found in more advanced commercial LMIS systems.

DSS Technology: Inventory Optimization using actual constrained optimization or simulation approaches

Overview: The most advanced systems conduct Inventory Optimization using actual constrained optimization or simulation approaches and tend to be bespoke solutions.

Current use: As described in the Inventory Optimization using interrelated rules section.

Maturity Level 3: An organization needs to have the capability to integrate constraints from different electronic information systems.

Process: As described under Individual calculations, however, inventory parameters are calculated jointly by DSS. The process still requires human verification of the results.

Skills:

- The supply planners/analyst need a basic understanding of the additional constraints and how they impact the inventory policy.
- Data scientists: Required to design, evaluate and maintain the DSS.

Data: As described in the Individual calculation section. In addition, cost data is required (product price, transport costs, warehousing costs).

System requirements: Medium, an underlying electronic system with integration to other systems is required.

Methods: More complex, and typically bespoke, systems can include additional constraints such as inventory cost, backorder cost, transport cost and potentially lot size by using meta-heuristic algorithms. These are processes that use a combination of rules and varying parameters in multiple (1000s) of simulations to find the best values for each parameter. These are not necessarily strictly optimal, as they only reflect the range of values simulated and the selection parameters. However, this type of algorithm is able to incorporate many constraints and provides robust solutions to problems that would otherwise be too computationally intensive. These systems typically require two or more years of data for each SKU to provide good results.

Other Supply Planning DSS

DSS Technology: Identify fast- and slow-moving inventory

Overview: Technique that categorizes the different goods in order to facilitate segmented inventory strategies that fit their product characteristics.

Current use: Used in non-PHDC that typically handle goods with different characteristics, such as retailers.

Maturity level 1: An organization needs to have inventory stock data stored in an electronic system.

Process:

- Develop inventory plan
    - Review inventory planning data.
    - Calculate revised safety stock.
    - Final inventory consensus and publishing.

Skills:

- The supply planners/analyst need a basic understanding of the different product categories and their characteristics.
- Data scientists: Required to design, evaluate and maintain the DSS.

Data: What, the location, a demand forecast, historical lead times, and the minimum order quantity.

System requirements: Medium, an underlying electronic system is required.

Methods: Rules or statistical distributions are used to help determine the safety stock levels of products that follow customary distribution patterns, as well as items with intermittent and lumpy demand. This allows planners to analyze demand patterns of items to help establish appropriate safety stock levels.

DSS Technology: Labor and Transport Capacity Planning

Overview: Labor and transport capacity are included as additional constraints in the inventory plan.

Current use: Used in non-PHDC that typically handle goods with multiple products and sales sites, such as retailers.

Maturity level 2 – 3: An organization needs to have inventory stock data frequently updated in the electronic system (level 2), in addition to integration with warehouse and transportation data (level 3).

Process: As described above for Identification of fast and slow-moving inventory.

Skills:

- The supply planners/analyst need a basic knowledge of how labor and transport capacity constraints might impact the inventory plan.
- Data scientists: Required to design, evaluate and maintain the DSS.

System requirements: Medium, an underlying electronic system with integration to other systems is required.

Data: Additional data on capacity constraints.

Method: Uses rules to assist users to take into account capacity constraints, e.g., warehouse or transportation labor, when determining inventory plans.

DSS Technology: Advanced price modeling

Overview: The future price is modeled to estimate the most optimal time to purchase the goods.

Current use: Used by some large companies where the price of goods or inputs is highly volatile. DSS are used to understand the drivers of the price and recommend when the organization should purchase or enter hedging contracts. This is relevant to some pharmaceuticals, particularly those that suffer global shortages or are heavily influenced by the prices or availability of inputs.

Maturity level 3: An organization needs to have an integration to external data that impact the price.

Process: Price modeling is incorporated in the supply plan.

Skills:

- The supply planners/analyst need a basic understanding of how external factors impact the price.
- Data scientists: Required to design, evaluate and maintain the system.

Data: Historical product price (difficult to obtain in closed markets) and external factors (relatively easy to scrape).

System requirements: Low.

Method: These DSS are based on a probability distribution of the price or machine learning models, depending on the degree of volatility. The applications are customized to a particular good, as the relationships are not usually generalizable, and as a result, these systems require significant maintenance as the relationships change frequently.

Inventory management

Visibility into and monitoring of stock levels are key focus areas for DSS both in PHDC and non-PHDC supply chains. More advanced DSS are also available, predicting inventory levels and optimizing allocation of stock across the supply chain network.

How much inventory do I have on hand?

DSS Technology: Dashboards and business intelligence platforms

Overview: Visibility into stock on hand data allows the decision-maker to make informed decisions on how to avoid stock out and minimize obsolete stock.

Current use: For organizations with a basic digital maturity, stock depletion is manually updated in an electronic information system on a regular basis. There are several examples of this in PHDC supply chains, where inventory data is updated according to scheduled intervals in the information system at the facility level.

For more digitally mature organizations, DSS monitor the current inventory level against the target inventory level and notifies the decision-maker when there is a risk of stock out or excess/obsolete inventory. Private sector companies are investing significantly in gaining visibility of stock and transitioning from a continuous monitoring way of working to inventory exception management.

There are examples of automated control of inventory in PHDC supply chains, where inventory data is updated at the facility level to enable a transparent overview of current stock levels (e.g. Field Supply, Mezzanine). The dashboards and the results from the data are often only available at a higher level and are not accessible to the health workers at the facility level.[90]

Maturity level 1 - 3:

- Maturity level 1: Staff view the stock take in their electronic tool.
- Maturity level 2: A transactional system captures stock levels and employs rules to monitor stock levels.
- Maturity level 3: Several warehouse management systems are integrated, with a DSS tool on top.

[90] Field Supply 2018, Mezzanine 2019 n.d.

Process:

- Regional warehouse
    - Review allocation targets and constraints.
        - Check availability of product.
        - Update max and min stock targets for each warehouse.
    - Set up allocations.
        - Conduct allocation quantity estimate.
        - Determine allocation per regional warehouse.
- Facility replenishment
    - Develop and iterate replenishment strategy, approach and plan.
    - Establish current inventory status.
    - Review replenishment targets and constraints (e.g. restrictions from regional warehouse).
    - Establish/update replenishment parameters (e.g. replenishment cycle).

Skills:

- Users
    - Strategic leaders: Translate the output of the inventory planning results into impact on national/regional availability.
    - Supply chain managers: Interpretation of results of the inventory planning.
    - Supply chain planners/analysts: Ensure accurate data input and run the models. Basic understanding of the logic of the models.
    - Supply chain operators: Accurate data entry.
    - Clinical staff: Accurate data entry.
- Data scientists: Required to design, evaluate and maintain the most advanced solutions as noted below.

Data: What, where, inventory date, inventory quantity, inventory type, safety stock, order quantity, order cost, holding unit cost, lead time, ship date, order date.

System requirements: Low to medium (if interoperability is required).

Method: This is the most basic question in Inventory Management and is the basic output of LMIS. Where there are multiple IMS a DSS layer using a Business Intelligence dashboard (for example a VAN) is often used to connect the systems and provide an overview inventory. The best DSS provide a visual representation of the stock and are able to provide information in terms of a variety of units (i.e. pallets and cases or cost in various currencies) and various aggregations across SKUs and levels of the supply chain.

How much inventory will I have on hand?

Overview: There are two common DSS functions that assist in answering this question, both based on rules.

Current use: The functionalities are commonly included in commercial LMIS systems, also in developing countries. Common functions include:

Projected inventory is calculated based on rules using the demand forecast and supply plan. This is usually generated using rules and data on current inventory and the demand forecast.

While not typically included in commercial LMIS, projected inventory can be calculated at any level in the supply chain. There is an opportunity to use projected inventory where facilities or other levels of supply chain have not provided actual inventory data or where the data is being collected or provided up the supply chain fast enough to be used in decision making.

Shelf-Life Support: Assists users to take account of products' shelf life when considering inventory and projected inventory based on rules.

Maturity level 1 - 2: An organization needs to have inventory, demand and supply data stored in an electronic information system (level 1). Preferably, the models should use transactional data to ensure that the inventory data is up to date (level 2).

Process:

- Facility replenishment
    - Develop and iterate replenishment strategy, approach and plan, taking into account demand and supply data.
    - Establish current inventory status.
    - Review replenishment targets and constraints (e.g. restrictions from regional warehouse).
    - Establish projected inventory levels.

Skills: As described under Dashboards and business intelligence platforms.

Data: What, where, inventory date, inventory quantity, inventory type, safety stock, order quantity, order cost, holding unit cost, lead time, ship date, order date, expected demand.

System requirements: Low to medium.

Method: Rule-based.

How should I distribute the stores I hold? Which locations should I prioritize?

DSS Technology: Individual calculations

Overview: There are a number of DSS functions that assist in the allocation of goods from a higher tier (i.e. central medical store) to lower tiers (i.e. regional warehouses) or between tiers at the same level (i.e. between facilities). In the PHDC context these functions can also assist in rationing decisions.

Current use: Frequently used in non-PHDC context to optimize the distribution of goods to warehouses according to the predicted demand. Common functions include:

Fulfillment support helps to determine which customer orders can be fulfilled with available supply in the short term based on rules.

Phase-Out Stock (run out) functions assist the user plan how to fulfill existing orders based on current inventory across the system for products that are being phased out based on rules.

Maturity level 1 - 3: An organization needs to have inventory data in an electronic information system (level 1). Preferably, the models should use transactional data to ensure that the inventory data is up to date (level 2).

Process: Process steps for inventory management need to be followed, however, inventory parameters are calculated by DSS. The process still requires human verification of the results.

Skills: As described in the Dashboards and business intelligence platform.

Data: What, where, inventory date, inventory quantity, inventory type, safety stock, order quantity, order cost, holding unit cost, lead time, ship date, order date, expected demand.

System requirements: Low to medium, depending on integration capabilities.

Method: Rule-based.

DSS Technology: Demand prioritization

Overview: These functions assist users to prioritize replenishment or customer orders. In the PHDC context these functions can also assist in rationing decisions.

Current use: Used in non-PHDC context where stock-outs have large consequences, for example in pharmaceutical products.

Maturity level 1 - 3: An organization needs to have inventory data in an electronic information system (level 1). Preferably, the models should use transactional data to ensure that the inventory data is up to date (level 2). Advanced systems may require an Inventory Management System integrated with the Order Management System (level 3).

Process: Process steps for inventory management need to be followed, however, inventory parameters are calculated by DSS. The process still requires human verification of the results.

Skills: As described in the Dashboards and business intelligence platform. In addition, an understanding of the logic and input into demand prioritization is required.

Data: What, where, inventory date, inventory quantity, inventory type, safety stock, order quantity, order cost, holding unit cost, lead time, ship date, order date, expected demand.

System requirements: Low to high, depending on method.

Methods:

The least advanced are rule-based. These can include customized settings or pre-defined rules like *fair share* or *informed push*. Some systems also include automation of stock transport orders based on the demand priorities that have been specified as part of this function.

For products where stockouts or customers' orders going unfulfilled have very negative consequences, like public health supply chains, there are some advanced bespoke DSS solutions used in the private sector (particularly pharmaceutical) which use more advanced techniques to prioritize rationing or back orders.

For the least complex problems, where there are few constraints, it is possible to use optimization, for example linear programming. For more complex problems metaheuristic algorithms can be used, as described in more detail under Inventory Optimization.

The most advanced systems use reinforcement learning techniques, which can provide good solutions to even the most complex problems, although they require large amounts of data, typically 1000s of replenishments/customer transactions. The advantage of these systems is that they can be used where the complexity of the problem is too large for strict optimization. The outputs are typically either lead to an automatic stock transport order or are flagged for human intervention.

Contract/ supplier management

Managing contracts with goods and service providers both up and down the supply chain can be very complex. Broadly there are two current DSS approaches to contract and supplier management, first in using a contract management approach, the second in terms of suppliers scoring. These bespoke DSS are described under the key question they assist the decision-maker in answering.

Are my suppliers meeting the contractual agreements?

DSS Technology: Contract management

Overview: Due to the number, size and complexity of contracts it can be difficult to assess whether suppliers are meeting their contractual arrangements. A simple example is the cost in resources of checking for differences in payment terms or price included in invoiced as opposed to the actual contract.

Current use: These DSS are typically used by companies with a complex contract landscape, typically handling main and sister contracts. The DSS has not yet been observed in PHDC supply chains. A significant challenge is that the procurement information systems are often manual and lacking data to assess contract performance. The contracts themselves provide adequate information through the application of Natural Language Processing.

Maturity level 3: An organization needs to have an integration with a Contract Management System or other systems capturing contract performance.

Process:

- Identify contractual obligations.
- Monitor contract performance and report any contractual breaches.
- Benchmark suppliers contract performance.

Skills:

- Users
  - Strategic leaders: Translate the output of the contractual and supplier performance into concrete actions towards the suppliers.
  - Supply chain managers: Interpretation of results of contract and supplier performance assessment.
  - Supply chain planners/analysts: Ensure accurate data input and run the models. Have a basic understanding of the logic of the models.
  - Supply chain operators: Accurate data entry to document receipt of goods and report any damage.
  - Clinical staff: Accurate data entry to document receipt of goods and report any damages.
- Data scientists: Required to develop, evaluate and maintain systems.

Data: Actual supplier performance, original contracts.

System requirements: High, the peak processing requirements mean that these systems are usually based on a server or on cloud.

Method: Bespoke DSS are being used in developed countries context that use Natural Language Processing to recognize and extract key contract terms into a database. The DSS automatically checks key details between actual suppliers' performance and the original contract, to name just a few examples, these include the actual lead time in comparison with the contractual lead time, the price per unit at a given volume, the quantity due and products/services in scope. The outputs from this system tend to feed into alerts that flag contract non-compliance.

How are my suppliers performing?

DSS Technology: Supplier performance monitoring

Overview: This type of DSS use historical data on supplier performance, including price, delivery accuracy and quality to calculate a supplier score. The DSS are also able to incorporate data on the type of contract or product to assess risk. These DSS are used in spend analysis, to identify where costs can be reduced by consolidating or changing suppliers and in risk analysis on where to direct human attention and how many suppliers should be used given the risk of a given type of product or service.

Current use: These DSS are used by companies with a large supplier landscape, such as manufacturers. DSS using these approaches have not been observed in PHDC supply chains. A significant challenge is that the procurement information systems are often manual and lacking data to assess supplier performance.

Maturity level 1 - 3: An organization needs to have systems integrated with a Supplier Performance Tool and other key systems capturing supplier performance (level 3).

Supplier performance monitoring can also be adopted through manual use of rules or automated rules (level 1 – 2). However, all data will then need to be added manually.

Process:

- Develop supplier KPIs (e.g. quality, delivery time, number of recalls).
- Perform regular supplier performance reviews.
- Benchmark suppliers against existing KPIs.

Skills: As described in the Contract management section.

Data: Accurate master data, data periodically updated on relevant features of a supplier's performance. The majority of shipments should be registered in order to have a sufficient volume for statistical analysis.

System requirements: High for model training, low for application.

Method: These systems classify transactions using supervised machine learning and compare them to benchmarks developed on other like transactions with other suppliers.

Warehouse management

There is a wide range of DSS in warehouse management, spanning from ad-hoc registration of data to fully automated and integrated warehouse management.

DSS Technology: Ad-hoc warehouse management

Overview: The system registers incoming and outgoing data on shipments on an ad-hoc basis. The data is used to generate basic recommendations on inventory management, such as the next recommended shipment based on the expiry date.

Current use: Used in both PHDC and non-PHDC that have access to an electronic system, but where the connectivity is limited and there is a lack of a defined digital warehouse management process.

Maturity level 1: An organization needs to capture data in an electronic information system on an ad-hoc basis.

Key processes:

- Receive shipments

    - Communicate and hand over from incoming transportation agent.
    - Collect shipment data (e.g. product attributes, sender, receiver e.g.).
- Manage shipments
    - Put the shipment in the warehouse.
    - Control specific conditions in the warehouse (e.g. cold chain).
- Send shipments

Skills:

- Users
    - Strategic leaders: Translate the output of warehouse management optimization tools into strategic actions on how to structure the warehouse.
    - Supply chain managers: Interpretation of inventory management results to ensure correct stock level of the warehouse.
    - Supply chain planners/analysts: Ensure accurate data input and run the models. Have a basic understanding of the logic of the models.
    - Supply chain operators: Accurate data entry.
    - Clinical staff: Accurate data entry of stock levels to inform the higher level warehouses.
- Data scientists: Not usually required in the supply chain.

Data: Product attributes (e.g. expiry date, dimensions).

System requirements: Low. It can be executed in spreadsheet software.

Method: Pre-defined rules monitoring the stock levels in the warehouse.

DSS Technology: Automatic warehouse management

Overview: The system registers incoming and outgoing transactional data on shipments. The data is used to generate automated recommendations on inventory management, such as the next recommended shipment based on the expiry date.

Current use: In both PHDC and non-PHDC supply chains we see a wide variety of DSS that address this question. DSS register stock status, the location of goods in the warehouse and provides recommendations on which supplies to ship next. Examples are the Ministry of Health in Mozambique and National Medical Stores in Uganda using MACS Software, which tracks the stock status and the location of the goods in the warehouse.[91]

Maturity level 2: An organization needs to capture transactional and product data in an electronic information system.

Process: As described under Ad-hoc warehouse management.

Skills: As described in the Ad-hoc warehouse management section.

Data: Product attributes (e.g. expiry date, dimensions).

System requirements: Medium.

[91] MACS Software 2019

Method: Pre-defined rules monitoring the stock levels in the warehouse, with the underlying data in an electronic system. Off the shelf warehouse management systems have these capabilities.

DSS Technology: Automated and integrated warehouse management

Overview: The system models warehouse operations, including incoming, current and outgoing stock/shipments. The system uses the information on incoming and outgoing shipments to automatically adjust current warehouse operations, including the location of shipments in the warehouse and capacity planning.

Current use: Used in non-PHDC with heavily integrated supply chain processes. The use has not been identified in PHDC supply chains.

Process: As described under Ad-hoc warehouse management, however, data integration with transportation providers eliminates the need for manual status check-ins with the providers.

Skills: As described in the Ad-hoc warehouse management introduction, however, warehouse managers need a basic understanding of how data on incoming and outgoing shipments impact warehouse operations.

Maturity level 3: An organization needs integration to other relevant upstream and downstream electronic information systems.

Data: Product attributes (e.g. expiry date, dimensions), transfer orders, sales orders, miscellaneous transactions, product shipment status.

System requirements: Medium. The DSS requires integration to other electronic information systems in the end-to-end supply chain, such as Order Management and Distribution Management.

Method: Off the shelf or bespoke DSS with automated rules and statistical analysis.

Distribution planning

Distribution planning can be divided into three broad time horizons; the long term, where all inputs are variable, the medium term, where assets such as warehouses and facilities are fixed, but transportation options are variable, and the short term, where all assets are fixed. Different DSS functions are applied to each of these timeframes, as outlined below under each key question below.

How should I structure my network in the long term?

DSS Technology: Network analysis/Digital twin

Overview: Network analysis determines the most optimal structure of the supply chain based on the demand and costs, and the ability to handle volume changes quickly.

Current use: Network analysis is typically used by private sector companies such as retailers with large production and distribution networks.

Maturity level 1: An organization needs the required data stored in an electronic information system, which is equivalent to level 1 on the maturity scale for Distribution Management. Real-time data is not required as this is typically a one-off analysis, however, the data in the system cannot be outdated.

Process:

- Collect required data on volumes, network capacity and cost (data collection).
- Model volumes (incl. seasonality) and capacity: Determine the demands for each network for each type of product that it must handle between each probable source and destination.

- Model number/size/location of nodes: Determine the optimal set of nodes and preferred modes of transport between these nodes based on product volumes and operational principles.
- Build cost-benefit scenario: Summarize the outputs of a network cost model and building what-if scenarios based on volumes and network configurations.
- Build detailed business case: Evaluate each network scenario in terms of operating and investment costs, impact on service levels, impact on inventory holding and business risk.

Skills:

- Users
    - Strategic leaders: Translate the output of the network into strategic structural changes.
    - Supply chain managers: Interpretation of results of how it will impact their everyday operations.
    - Supply chain planners/analysts: Ensure accurate data input and run the models. Have a basic understanding of the logic of the models, and have an understanding of how different distribution parameters and costs affect the end-to-end supply chain.
    - Supply chain operators: Accurate data entry.
    - Clinical staff: Accurate data entry.
- Data scientists: Required to design, evaluate and maintain bespoke systems.

Data: Typically units of transport (type, capacity), facilities (location, capacity, demand), relationships between facilities (schedules, times), processes like warehousing, sorting, packing, dispatching (times, costs, capacity).

System requirements: Low.

Method: For the end-to-end supply chain, simulation software can be used to develop a model of the supply chain (or digital twin). This model is used to test varying supply chain scenarios, for example:

- Can we conduct a direct delivery from the port to the facilities in one region?
- Do goods need to pass through all of the supply chain nodes?
- Would an additional warehouse in a given location be cost effective?

As these are bespoke systems they can potentially be developed to use program specific measures of value (i.e. number of children vaccinated, disability-adjusted life years, etc.).

Developing these models requires specialized planning software and skills, but the resulting models can be used by supply chain managers without technical skills in the model development process. Updating the parameters in the models can be done by the end users through for example uploading a spreadsheet.

How should I structure my network in the medium term?

DSS Technology: Flow path optimization

Overview: Flow path optimization helps the decision-maker move goods through the supply chain. This type of DSS functionality is often used where you already have a network (plant, distribution, client) and demand from the final client but need to decide the best flow for the product to fulfill that demand.

Current use: Network analysis is typically used by private sector companies such as retailers with large production and distribution networks.

Maturity level 2 - 3: The required maturity depends on the constraints in the decision-making problem, however, automated calculations (level 2) and system integration (level 3) are typically required.

Process:

- Build and align on a model of the supply chain that includes all relevant nodes of your supply chain.

- Collect required data on the shipment and input the characteristics of your shipments into the model.
- Assess and decide on the most optimal flow path for the shipment.

Skills: As described in the Network analysis section.

Data: Capacity of all nodes, processing time, forecast demand, cost of operations, existing transport, potential alternative transport.

System requirements: Low to high, depending on the constraints in the decision-making problem. Solutions tend to be on cloud.

Method:

These DSS are generally bespoke applications customized to a particular supply chain by optimizing multiple parameters, for example time and various costs. For simple supply chains and problems incorporating few constraints, algorithms typically use linear programming.

The most advanced systems use meta-heuristic algorithms, as described under Inventory Optimization. Meta-heuristic algorithms provide better results where there are complex constraints and where there is a high degree of variability in parameters (i.e. lead time or forecast demand).

How do I organize transport routes in the short term?

DSS Technology: Route planning

Overview: Route planning software identify the best transportation solution based on the value, dimension, urgency and regulatory requirements of the shipment.

Current use: Route optimization is frequently employed by the private sector, from global shipping and transport companies to local food delivery companies. Route optimization is also conducted in PHSDC supply chains. However, it is typically based on infrequent updates (e.g. one time, annually, every few years) rather than near real-time updates.

Maturity level 1 - 2: An organization needs to capture transactional data in a system to perform route planning (level 2). The planning can also be performed on data that is added on an ad-hoc basis (level 1).

Process:

- Outbound processing
    - Determine the outbound deliveries.
- Manage shipments
    - Determine journey plan (i.e. which nodes should be visited and what route should be taken).
    - Build vehicle loads (i.e. build the loads so that it minimizes time at each delivery point).

Skills:

- Users
    - Strategic leaders: Translate the output of the distribution planning into strategic structural changes.
    - Supply chain managers: Interpretation of results of the distribution planning.
    - Supply chain planners/analysts: Ensure accurate data input and run the models. Have a basic understanding of the logic of the models, and have an understanding of how different distribution parameters and costs affect the end-to-end supply chain.

    - Supply chain operators: Accurate data entry.
    - Clinical staff: Accurate data entry.
- Data scientists: Required to design, evaluate and maintain bespoke systems.

Data: Transport orders, urgency, regulatory or other requirements, capacity restrictions. It is not a requirement to capture data in real-time, however, the data should be updated frequently (e.g. 1-day lag) in order to improve the accuracy of the recommendations.

System requirements: Typically at least route recommendations services accessed from on cloud.

Method: Typically the algorithms compare the shipment input data with data on the supply nodes (e.g. location, current capacity, restrictions (e.g. not equipped to handle cold chain)) and other external data (e.g. weather forecasts) based on rules. The systems also include recommendations on how to organize goods within the transport given the route.

Where there are high quality road network information and traffic data from third parties more advanced systems also include 3rd party route recommendations based on the condition of the roads and estimated traffic.

DSS Technology: Expected time of arrival and delay prediction

Overview: DSS can monitor the movement of products in the end-to-end supply chain using data on the supplies as they pass through each supply chain node (e.g. port, central warehouse, regional warehouse, etc.).

Current use: DSS monitor the flow of the supplies and alert the decision-maker if any of the supplies are behind schedule. There are several examples of this in PHDC supply chains, where the movements of goods are typically registered in the electronic system at every node (e.g. distribution centers, warehouses, etc.) in the supply chain (e.g. Entuition Vesta – eLMIS Bileeta, Open LMIS).[92] For more mature supply chains, real-time stock movements are registered in the electronic system (e.g. Field Supply).[93]

Maturity level 3: The organization needs data integration to all the supply chain nodes.

Process:

- Track shipments
    - Monitor the shipment in the system as required.
    - Recognize deviations.
    - Determine corrective actions.

Skills: As described in the Route planning section.

Data: Transactional data including the what, the location and state of the goods at the transaction. It is not necessary to have real-time data, however, the data needs to be updated within a short time frame (i.e. within a day) for the systems to be useful.

System requirements: Low to medium.

Methods:

The expected time of arrival is calculated based on the location of the goods and either the contractual or historical time between nodes using rules. This calculation is included in many commercial LMIS.

[92] Bileeta 2017, OpenLMIS 2019
[93] Field Supply 2018

Prediction of delays uses transport monitoring to identify where delays occur. More advanced DSS use supervised machine learning algorithms to identify other key reasons supplies are delayed. These can be applied to the characteristics of current shipments in order to determine which of the current shipments has a high probability of being delayed. The decision-maker can therefore have a particular focus on these shipments or make contingency arrangements.

DSS Technology: Digital platforms

These DSS that match buyers and sellers also offer opportunities for outsourcing distribution and meet the broad definition of DSS in that they assist the decision-maker by providing them with information about a wider variety of options.

Current use: Some of the most successful existing online platforms that tackle the last mile delivery provide a valuable template and some platforms already exist in developing countries (i.e. Logistimo (Tusker) in India, Mozambique and Uganda).[94] The systems use a mobile platform to enable anybody with a registered vehicle to take on transportation jobs for rural freight. The service aggregates demand and allocates that demand to an appropriate transporter and tracks the shipment throughout the process. Transport companies gain access to a wider market and distributors gain access to a wider range of providers.

The inability to realize economies of scope in distribution drives up the cost of transport in public health supply chains.[95] This type of DSS also offers an opportunity to exploit economies of scope by accessing a wider range of transport options to reduce cost and increase resupply frequency.

Quality Assurance

There are two different DSS approaches for Quality assurance. The first approach addresses the quality of the good during transport and at the warehouse. The second approach addresses the authenticity of the good.

How do I monitor quality?

Overview: The temperature during transport and storage is monitored and alerts are sent if there is a risk that the goods (e.g. vaccines) will be damaged by the temperature.

Current use: This method is typically used by industries transporting supplies with special requirements, such as food producers and pharmaceutical companies. There are examples of remote temperature monitoring in PHDC supply chains, even though the current work is on a limited scale. An example is ColdTrace, a wireless remote temperature monitoring solution that is designed for vaccine refrigerators in rural health facilities and clinics. The wireless device tracks the temperature and sends a notification via SMS to key health personnel if the vaccines are in danger. Personnel are able to quickly respond to the alerts, avoiding damage to the vaccines.[96]

Maturity level 2 - 4: For the most basic applications, a data logger and an alert system is required (maturity level 2). For the more advanced applications, real-time temperature monitoring integrated with the other supply chain management information systems are required (maturity level 4).

Process:

- Define quality parameters (e.g. temperature min/max levels).
- Perform continuous monitoring.
- Recognize deviations.

[94] Logistimo 2019
[95] Yadav, Stapleton, & van Wassenhove 2010
[96] Nexleaf Analytics 2019

- Take mitigating actions and assess the need for continuous improvement.

Skills:

- Users
    - Strategic leaders: Translate the output of the quality assurance process into actions on how to either improve the process or withdraw products from facilities.
    - Supply chain managers: Interpretation of results of the quality assurance process.
    - Supply chain planners/analysts: Ensure accurate data input and run the models. Have a basic understanding of the logic of the models, including quality monitoring.
    - Supply chain operators: Accurate data entry and basic understanding of the devices (e.g. temperature devices).
    - Clinical staff: Accurate data entry and a basic understanding of the devices (e.g. temperature devices).
- Data scientists: Not usually required in the supply chain.

Data: Transactional data including product identification, the location and state of the goods (temperature) at the transaction.

System requirements: Medium to High.

Methods:

DSS monitoring telematics in devices such as temperature sensors in refrigerators can be used to continuously monitor equipment. This is particularly valuable in ensuring the correct temperature is maintained in cold chain equipment during transport, warehousing and at the POS. Using these types of data feeds, DSS can equip the decision-maker to immediately intervene in situations where there is a risk of damage to medicines or vaccines, allowing only safe supplies to reach patients.

Predictive maintenance can be employed to prevent equipment breakdown and increase equipment working life, for example, sensors in vehicles, regenerators and the warehouse itself. As well as improving the response to equipment failure, supervised machine learning algorithms are trained using the readings from the sensors to predict the need for maintenance and alert maintenance staff proactively to avoid a breakdown.

How do I monitor authenticity?

Overview: The origin of the product is tracked throughout the end-to-end supply chain by comparing a digital ID to the physical product, to avoid that counterfeited goods reach the end patients.

Current use: Authenticity monitoring is typically used by private sector companies transporting high value goods. There are also examples of DSS providing authenticity verification in PHDC supply chains, such as the GS1 Verification Platform in Ethiopia[97] and TruScan in Nigeria.[98] The solutions are based on barcoding of the commodities that are used to verify the authenticity.

Maturity level 3: An organization needs end-to-end system integration to track and trace a product electronically.

Process:

- Register product identification (e.g. serial number) in an electronic system.

[97] GS1 2019
[98] PwC 2017

- Scan the product identification at each node in the supply chain.
- When issues are identified, take mitigating actions to remove the counterfeited goods from the supply chain.

Skills:

- Users
    - Strategic leaders: Translate the output of the quality assurance process into actions on how to either improve the process or withdraw products from facilities.
    - Supply chain managers: Interpretation of results of the quality assurance process.
    - Supply chain planners/analysts: Ensure accurate data input and monitor the continuous tracking process.
    - Supply chain operators: Accurate scanning of product ID.
    - Clinical staff: Accurate scanning of product ID.
- Data scientists: Not usually required in the supply chain.

Data: Product identification (e.g. barcode, QR code, RFID).

System requirements: Medium, an electronic system is required.

Method: Tracking and verification systems can verify the identity from the POS to the manufacturer, and provide stakeholders the ability to verify the authenticity of the product and act in case the product is counterfeit or defective. Transactional data collected from barcodes, RFID and telematics can provide end-to-end track and trace data that can be used to identify counterfeit goods and help identify the location that they enter the supply chain. Simply including a barcode or QR Code on the packaging with a link to providence information puts consumers in a position where they can trace the providence of the medication and make an informed consumption choice.

Appendix C: DSS Journey

The overview below describes each DSS maturity step and outlines which capabilities supply chains actors typically invest in across technology, people and process at each maturity step to realize the full potential of the DSS.

AD-HOC

Data is registered in a paper-based or electronic information system on an ad-hoc and manual basis. The decision-makers are unable to consistently use data in routine decision-making, monitor the supply chain or consistently react to exceptions.

Typical capabilities supply chain actors invest in

Technology

Paper based or electronic system that contains data used in decision making.

Process

Supply chain managers or analysts are present to approve/act on the ad-hoc decisions supported by data.

People

The users and leaders understand how data can support their ad-hoc decision-making.

REACTIVE

Transactional data is entered in an electronic information system. DSS provide descriptive historical information and support some routine decisions (e.g. through calculations and recommendations) to some silos within the supply chain. Decision-makers use DSS to support routine decisions, monitor activities within their node and to manually identify exceptions.

Typically, we see supply chains DSS employing rule-based recommendations on some routine decisions within their functional supply chain silo (e.g. safety stock alerts, re-ordering recommendations).

Typical capabilities supply chain actors invest in

Technology

Data relating to the key supply chain decision points is stored in an electronic format (e.g. a LMIS) on a routine/continuous basis. A visualization tool (e.g. dashboards) is integrated. Basic thresholds/rules for DSS-generated recommendations are integrated.

Process

Key decision points in the supply chain processes that can be supported by technology and roles responsible for the decision points are defined.

People

The users and leaders understand the value data has in consistent decision making and trust the outcomes of the analysis.

RESPONSIVE

Functional information systems are integrated across the supply chain. DSS provide descriptive historical information and support many routine decisions (e.g. through calculations and recommendations) using data from nodes along the supply chain. Decision-makers use DSS to support routine decisions, monitor activities in the end-to-end supply chain and to manually identify exceptions in (other) nodes that will affect their node.

Typically, we see supply chains DSS employing rule-based recommendations on routine processes that incorporate information from the end-to-end supply chain (e.g. transportation tracking, allocation of stock between warehouses).

Typical capabilities supply chain actors invest in

Technology

Different information systems are integrated across the supply chain and between other relevant external sources.

A data governance model is established, defining what data points to share, frequency and ownership of data.

Process

A process for data sharing is defined across the different supply chain nodes that breaks down functional silos.

Roles responsible for data sharing are defined.

People

The users and leaders are aware of the value of data sharing and the synergies that can be created across the supply chain.

EVENT DRIVEN

DSS are used to automate routine decisions, monitor activity and alert decision-makers to exceptions in the supply chain requiring their attention. Decision- makers focus on exceptions rather than routine tasks to mitigate the impact of exceptions further up the supply chain on their node.

Typically, we see supply chain DSS employing rules or algorithms that automatically monitor processes in the end-to-end supply chain and execute operations according to data on the current performance (e.g. automated ordering, automated adjustments of warehouse operations based on volume flow) and that identify and relay information on exceptions to the decision-maker.

Typical capabilities supply chain actors invest in

Technology

Process

People

Advanced DSS are implemented:

- Monitor and automate routine decisions.
- Identify exceptions as they occur in the supply chain.
- Alert relevant decision-makers when human action is required.

Key processes are defiend:

- Tasks that are monitored and handled by the system.
- Fast-tracking exceptions to actors capable of making the correct decision.

Role responsible for acting on all the exceptions are defined.

The users and leaders are aware of the value of employing automated monitoring and an event driven supply chain.

PROACTIVE

DSS predict future events before they occur and automatically integrate it into automated routine tasks (e.g. demand sensing). Decision-makers focus on future exceptions to mitigate them before they impact the supply chain.

Typically, we see supply chain DSS employing advanced predictive algorithms that automatically adjusts the supply chain operations based on the predictions.

Typical capabilities supply chain actors invest in

Technology

Advanced DSS are implemented:

- Identify future events that are likely to affect the supply chain through predictive algorithms.
- Automatically integrate predictions into supply chain operations.
- Alert relevant decision-makers when human action is required.

Process

Key processes are defined:

- Linking key decision-maker to each predicted event.
- Thresholds for manual monitoring and intervention.

Roles responsible for monitoring proactive systems, including accuracy, bias and false alarms, are defined.

People

Users and leaders understand the value of employing proactive supply chain management.

There is a basic understanding of the underlying algorithms.

Appendix D: Summary of Supply Chain Information Systems Maturity Across Levels and Functions

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
MASTER DATA MANAGEMENT	Standardized common list of products	Common master data system	Integrated systems with GS1 identifiers and attributes	Master data systems integrated with Global Data Synchronization Network
INTEROPERABILITY	Standardized data exchange formats for exchanging data manually through uploads	Standard data message format and protocols in place for systems to exchange data electronically	Interoperability layer to manage data exchange across various systems	Minimized effort to plug and play additional systems to the interoperability layer to exchange data
TRACK & TRACE	Basic ability to identify, track and trace commodities manually	Automated tracking and tracing across 2 - 3 supply chain levels	Automated tracking and tracking across all supply chain levels and ability to authenticate commodities based on batch numbers	Product serialization and advanced tracking, tracing and authentication of commodities based on serial numbers
FORECASTING & PLANNING	Basic Forecasting, Supply Planning, and Distribution Planning	12 Month Rolling Forecast, with integrated Supply Plan, and Multi-level Distribution Plan with Min/Max Replenishment	Collaborative Demand Management, with Advanced Supply Chain Planning (constraint-based), and Distribution Plan integrated with transportation plan	Advanced Demand Management (with advanced algorithms and consensus managed forecast adjustments), real-time and collaborative Supply Planning, and Transportation Constrained Distribution Planning
PROCUREMENT	Basic procurement processes manually managed	Procurement process managed through the system	Automated procurement process workflows	Integrated system to facilitate automated processes
WAREHOUSE MGMT.	Basic Warehousing Operations (Manual, if not automated)	Warehousing Operations through electronic data, barcodes and system managed transactions	Real-time Transaction Processing and Automated workflow management for warehouse personnel	Advanced Warehousing including Serialization and Exception Management
SUPPLIER & CONTRACT MGMT.	Basic system to manually capture supplier and contract information	System driven sourcing and contract management processes	Automated sourcing and contracting process through workflow management	Integrated and collaborative system facilitating system driven end-to-end sourcing and contracting process
ORDER MGMT.	Basic Requisitioning & Fulfilment (Manual, if not automated)	System driven Requisition capture & Fulfilment	Predictable Requisition Processing & Fulfilment	Advanced Inventory Visibility & Exception Management

TRANSPORT MGMT.	N/A	N/A	Basic system to track transportation stages	Automated route management, transportation tracking and freight bill payment processing

Source: USAID 2018, Supply Chain Information Systems – Maturity Reference Model

Appendix E: Research Method

This appendix details the key questions and research design/methods that underpins the project: Opportunities to Transform Public Health Supply Chains in Developing Countries using Decision Support Systems.

Key Questions & Research Framework

This research has been structured around a central guiding question with supporting/sub-questions to guide aspects of the research. That central questions are:

> How can DSS be used to improve performance in Public Health supply chains in developing countries?

The supporting questions for each phase are:

Phase 1:

1. How does the industry understand DSS as a term, and what is the distinction and overlap between DSS with related terms such as business intelligence, control towers, and operational supply chain/logistics information systems?
2. How and what types of DSS are used for supply chain management within the private sector, including developing country contexts?
3. What applications of DSS are currently being used within PHDC supply chains?
4. What applications of DSS are used in and appropriate for limited data and data-poor contexts?
5. What are the limitations and barriers that explain why DSS is not more used within PHDC supply chains, including (but not limited to) issues around data availability, data quality, infrastructure, workforce competencies, and general lack of familiarity with such systems?

Phase 2:

6. What are potential use-cases for DSS in PHDC supply chains?
7. What are the types of DSS that are most appropriate for specific public health supply chain tasks or problems?
8. What are the likely data, system, and supply chain requirements needed for successful adaptation of differing types of DSS (including a minimum set of requirements/criteria needed for successful implementation)?
9. What skill sets will be required in-country for PHDC supply chains to successfully use the recommended types of DSS?
10. How does data availability and data gaps in-country systems affect the utility of DSS?
11. What DSS, if any, are well-suited to data-poor environments?
12. What are likely barriers to successful implementation (e.g., in terms of people, processes, technology and change management) that will need to be addressed in design and implementation?
13. What efforts will be needed to develop/adapt appropriate DSS to the PHDC supply chains?

14. What are the key factors that donors need to consider and incorporate when supporting DSS for PHDC supply chains to maximize the likelihood that the investments will be sustained by national governments without continued, long-term donor support?
15. What are the most profitable areas for donor investment to support progress in this area?

Research Design and Methods

Overview

This research collected data through both primary and secondary research. The primary research focused on in-depth semi-structured interviews. This was supported by a structured survey, which allowed a shallower but wider view of DSS digital and supply chain maturity, use cases and challenges. The secondary research was conducted through desktop research of both publicly available information and partner documents and data.

Semi-Structured Interviews

This method has been chosen as it is an effective and convenient means of gathering information relevant to the study.[99]

The advantage of in-depth interviews is that they provide much more detailed information and the opportunity to clarify the participants' perspectives during the interview. This method also enables interviewees to provide responses in their own terms and in the way that they think and use language. Additionally, it adds flexibility to the interviewer in terms of the ability to modify the style, pace and ordering of questions to evoke a more complete response from the participant.[100]

This method of data collection can be subject to bias both from researchers where their interests relate to a specific outcome. There is also the risk that participants can be biased due to their stake in the findings or to please the perceived interests of the interviewers.[101] These risks were mitigated by maintaining an awareness of the interests of the parties and through questionnaire design and by the interviews being conducted by the consultancy partner.

Population and Study Sample

The population from which the interview sample was drawn from are:

- Stakeholders of our partner organizations, who represent a sample of supply chain practitioners.
- Private sector companies with connections to Accenture SMAs, who represent a state-of-the-art and future-looking vision of DSS.
- Organizations known to be implementing advanced decision support systems in their supply chains through prior engagements with Accenture.

The sample for interview was 40 participants drawn from all groups, with the majority drawn from partner stakeholders. In total, 37 have been interviewed to date. Due to the small sample size and structure of the sample, there will be a limited ability to generalize outside of the populations interviewed.

Surveys

[99] Kvale & Brinkmann 2009
[100] Qu & Dumay 2011 p246
[101] Boyce & Neale 2006 p4

Surveys have the advantage of being able to collect comparable data from a large sample of respondents. These provide a broader benchmark on DSS digital and supply chain maturity and information on DSS use cases and challenges. The target group for the survey are practicing supply chain managers and supply chain consultants from across industries and geographies. Participants for the survey were recruited by approaching communities of practice and professional associations and circulating the survey within Accenture´s supply chain practices.

Population and Study Sample

The primary challenge in survey design is ensuring the sample represents the population of interest. In this study, the size and characteristics of the population of interest are unknown. This means that caution has been taken in generalizing the results. To mitigate the risk of systematic bias, demographic information about the sample was collected, so that although it is not possible to generalize to the entire population of supply chain practice, there is the ability to make careful generalizations to populations which have similar characteristics to the sample.

There is a trade-off between survey length and non-response at the survey and question level. Non-response is unlikely to be random and can be an important source of survey bias. To ensure a good response rate the survey was kept as short as possible while collecting the required information.

Secondary research

The secondary research was collected through review of appropriate public literature, Accenture documents and data and the documents and data supplied by our partners.

Secondary research sources of data

Secondary research will incorporate three main sources of data:

- Partner documents and data
- Documents, data and input from Accenture SMAs
- Publicly available data including current professional literature, academic literature/journals, pertinent websites and databases.

Data Management

Confidential data collected from interview participants is stored securely within Accenture systems. Notes are held by Accenture and summarized findings provided to partners.

Appendix F: Interview List

We would like to acknowledge and thank the many people who contributed to this work, including the individuals listed below that participated in interviews.

Participation

- Number of interviews: 37
- Number of individuals: 46
- Number of organizations: 21

Name	Organization and roles	Type
Pedro Bejar	Accenture, Managing Director Supply Chain	Private Sector Supply Chain
Angels Tornero	Accenture, Managing Director Supply Chain	Private Sector Supply Chain
Silje Haugland	Accenture, Strategy Consultant Control Tower	Private Sector Supply Chain
Esteban Sadurni	Accenture, Senior Manager Control Tower	Private Sector Supply Chain
Lau Pera Itxart	Accenture, Intelligent Planning Lead, Barcelona Supply Chain Innovation Center	Supply Chain Analytics
Franz Naselli	Accenture, Intelligent Procurement Lead, Barcelona Supply Chain Innovation Center	Supply Chain Analytics
Roman Buil Gine	Accenture, Intelligent Logistics & Execution Lead, Barcelona Supply Chain Innovation Center	Supply Chain Analytics
Gaston Besanson	Accenture, European Health Lead, Applied Intelligence	Health Analytics
Tomas Mato Amboage	Accenture, Sustainability Analyitcs Lead, Applied Intelligence	Supply Chain Analytics

João Carriço	Adicional Moçambique	Private Sector Supply Chain in Africa/LMICSs
R. S. Sanji De Silva	Bileeta, CEO	Software Solutions/Service Providers
David Sarley	BMGF, Senior Program Officer	Partner
Ralph Titus	Chemonics/GHSC-PSM, Director, Health Systems Strengthening	Global Health Implementing Partners
Andrew Inglis	Chemonics/GHSC-PSM, Advanced Analytics Manager	Global Health Implementing Partners
Hua Ni	Chemonics/GHSC-PSM, Supply Chain Optimizatoin & Excellence Manager	Global Health Implementing Partners
Donovan de Klerk	DSV, Senior Team Lead, Inventory Optimization	Private Sector Supply Chain in Africa/LMICSs
Piet Van Dyk	DSV, General Manager: Supply Chain Innovation, Africa	Private Sector Supply Chain in Africa/LMICSs
Kelly Thompson	E2Open, Area Sales Director	Software Solutions/Service Providers
Kathy Ferree	E2Open, Senior Program Director	Software Solutions/Service Providers
Michael Moreland	Field Intelligence, CEO	Software Solutions/Service Providers
Justin Lorenzon	Field Intelligence, CTO	Software Solutions/Service Providers
Alfons Van Woerkom	Global Fund, Head of Supply Chain	Donors/UN Organizations
Mouna Jarmouni	Global Fund, Head of Supply Chain Data & Performance	Donors/UN Organizations

Rob Botha	Guidehouse, Chief of Party, Global Health Supply Chain	Global Health Implementing Partners
Edward Wilson	JSI, Director, Center for Health Logistics	Global Health Implementing Partners
Paul Dowling	JSI, Senior Technical Advisor	Global Health Implementing Partners
Marasi Mwencha	JSI/Ethiopia, Country Director, AIDSFree	Global Health Implementing Partners
Naomi Printz	JSI/Tanzania, Country Director	Global Health Implementing Partners
Muhammad Ghous Afzal	Kolonial, Head of Transportation	Private Sector Supply Chain
Stew Stremel	Lightwell LLC, Consultant on Supply Chain Visibility Maturity Landscape	Global Health Implementing Partners
Jessica Vernon	Maisha Meds, CEO and Co-Founder	Software Solutions/Service Providers
George Munyi	MEDS, Mission for Essential Drugs and Supplies (Kenya)	Private Sector Supply Chain in Africa/LMICSs
Manuel Celestino Lavayen	UNICEF, Supply Chain Manager	Donors/UN Organizations
Erfan Hesamadini	Omego Fleet, Co-Founder & Chief Innovations & Logistics Officer	Private Sector Supply Chain
Brian Tailisen	PATH, Director	Partner
Matt Morio	PATH, Business Analytics Officer	Partner
Pat Lennon	PATH, Portfolio Leader, Supply Systems and Equipment	Partner
Max Kabalisa	PSM Nepal and Rwanda, Country Director	Global Health Implementing Partners

Saif ur Rab	PSM Nepal and Rwanda, Technical Director	Global Health Implementing Partners
Peter Lever	Therefore Strategic Technology Services	Private Sector Supply Chain in Africa/LMICSs
Meaghan O'Keefe Douglas	USAID, Supply Chain Monitoring and Evaluation Technical Adviser	Partner
Sharmila Raj	USAID, Systems Strengthening Team Leader	Partner
Lindabeth Doby	USAID, Sr. Supply Chain and MIS Advisor	Partner
Murray McArthur	Vitalliance, Chief Revenue Officer	Global Health Implementing Partners
Diane Reynolds	Vitalliance, Health Transformation Specialist	Global Health Implementing Partners
Gene Trousil	Vitalliance, CEO	Global Health Implementing Partners

About Us

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ABOUT USAID. USAID leads international development and humanitarian efforts to save lives, reduce poverty, strengthen democratic governance and help people progress beyond assistance. USAID is the world's premier international development agency and a catalytic actor driving development results. USAID works to help lift lives, build communities, and advance democracy. USAID's work advances U.S. national security and economic prosperity; demonstrates American generosity; and promotes a path to recipient self-reliance and resilience.

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