

APPLICATION OF SYSTEMS ANALYSIS AND OPERATIONS RESEARCH METHODOLOGY IN THE EXECUTION AND CONTROL OF BUSINESS LOGISTICS PROCESSES

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Abstract

This article outlines the analytical basis of logistics. The concept of logistics management is described in a business context, and its strategic, tactical and operational tiers are discussed. The relationship that exists between systems analysis and logistics management is indicated. The seven consecutive steps in the systems analysis process are outlined. The role and essence of operations research in systems analysis and business logistics decision-making are described. The most pertinent operations research applications in the field of logistics management, as well as the analytical competencies that a logistician should possess, are identified. The role that operations researchers can fulfil in the successful execution and control of business logistics processes are detailed.

Keywords: Business Logistics Management, Control, Operations Research, Supply Chain Management, Systems Analysis

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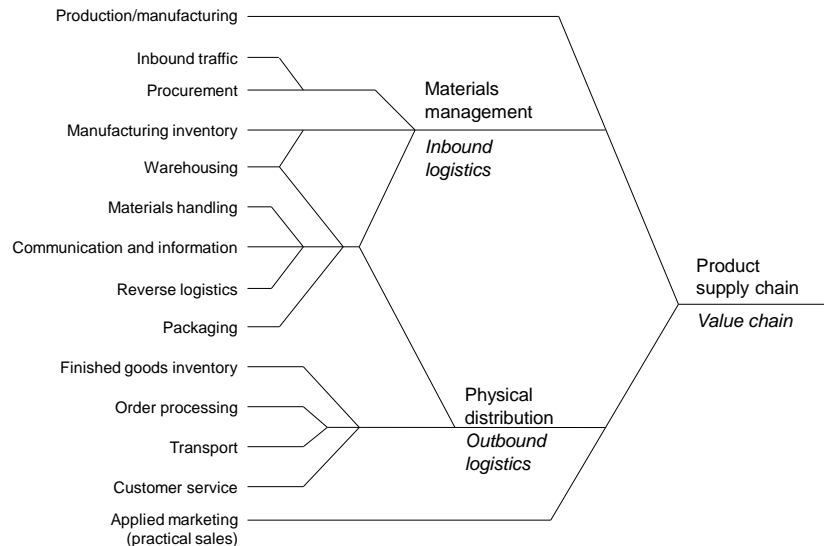
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1 INTRODUCTION

The purpose of this article is to outline the coherence that exists between logistics management and systems analysis, and to indicate the critical role that operations researchers can fulfil in the efficient and effective execution and control of business logistics processes.

The Council of Supply Chain Management Professionals (CSCMP), the world's major professional organisation for supply chain management and logistics, defines logistics management as 'that part of supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information

between the point of origin and the point of consumption in order to meet customers' requirements' (CSCMP 2011). Figure 1 indicates that logistics management, production/manufacturing and applied marketing (i.e. practical sales) collectively constitute supply chain management. As Figure 1 shows, the logistics management process can be divided into materials management (i.e. inbound logistics activities) and physical distribution (i.e. outbound logistics activities). Systemic cohesion among the activities shown in Figure 1 is achieved through coordinated and integrated strategic, tactical and operational management, shown in Figure 2 (Pienaar & Vogt 2009: 12).

Figure 1. Composition of logistics and supply chain management activities

Source: Pienaar & Vogt 2009: 12

The definition of the concept of logistics management supplied above is the one that is generally accepted in contemporary business logistics management literature. Important implications of the definition are discussed below.

First, as the definition indicates, logistics management encompasses the functions required to (1) prepare (plan); (2) organise and implement; and (3) execute and control the activities of a firm when distributing materials or finished products to customers (Bowersox et al. 2010: 327). Preparation and planning activities include the selection of facility sites (including type, number, location, size and capacity); durable equipment needed to facilitate the flow of products through the logistics network; distribution parties, including wholesalers, retailers and third-party service providers; and carriers (including choice of transport mode) required to offer services at the level demanded by customers to achieve the goals of the firm. The organisational and implementation aspects of logistics management include, firstly, the allocation and positioning of resources, and, secondly, the scheduling of production and distribution activities to respond to customer needs in an efficient manner in order to achieve the firm's objectives. Execution includes operational aspects (i.e. ongoing daily activities, such as stock keeping, routing trips, and scheduling deliveries, vehicles and crews), and control includes monitoring and reviewing performance (such as quality of service, expenditure, productivity and asset utilisation) to ensure that the logistics process satisfies customers effectively, the organisation's resources are

deployed efficiently, and corrective action is taken when performance is not in line with goals (see Figure 2).

Second, because logistics management revolves around planning, organising and executing/controlling the logistics process, it encompasses many of the firm's activities, from the strategic level to the tactical and operational levels (see Figure 2). Logistical decisions are typically classified in the following way (Ghani et al. 2004: 18; Simchi-Levi et al. 2004: 12):

- The *strategic* level (i.e. preparation and planning) deals with decisions that have a long-lasting effect on the firm. Because data is often incomplete and imprecise, strategic decisions are generally based on aggregated data (obtained, for example, by grouping individual products into product families, and aggregating individual customers into customer zones).
- The *tactical* level (i.e. organisation and implementation) includes decisions that may be updated at various intervals from monthly to annually. Tactical decisions are often based on disaggregated data.
- The *operational* level (i.e. execution and control) refers to day-to-day decisions, which are customarily based on detailed data.

Third, an objective in logistics management is to consistently be efficient and effective across the entire system. This objective can be achieved by minimising system-wide costs, from transport on the one hand to warehousing and keeping inventory of raw materials, semi-finished goods and finished products on the other. Therefore, the emphasis is not simply on

selecting the cheapest or swiftest physical distribution method or on reducing inventories, but on an integrated and coordinated systems approach to the logistics supply chain process. The integrated total-cost systems concept is the trade-off of all costs that are in conflict with each other and that may affect the outcome of a particular logistics decision. The acceptance of the total-cost systems concept has therefore changed the relative importance of the different logistics activities.

Logistics systems analysis relies on operations research. The principles of systems analysis and operations research are logically consistent. Therefore, an integrated logistics process with cross-functional coordination, achieved through the application of operations research methodology, should lead to better results than one lacking coordinated performance.

2 SYSTEMS ANALYSIS: DEVELOPMENT AND BACKGROUND

Systems analysis is a dynamic problem-solving and decision-making process that encompasses the identification, study and evaluation of interdependent parts and their attributes that function in an ongoing process and that constitute an organic whole (APICS 2005: 114). Various alternative solutions to a problem and approaches to an overall design are considered in order to arrive at an acceptable system with optimum performance in terms of specific criteria.

It is generally acknowledged that systems analysis derives from operations research, which developed at the beginning of World War II (*Progressive Architecture* 1968: 112). At that time, scientists from various disciplines contributed to the development of specific types of armaments, supporting armaments and other innovative inventions. These armaments could not function properly unless the way they were developed by various people was understood. A multidisciplinary team was, therefore, formed to design methods to ensure the concerted optimum application of all available armaments. This procedure was so successful that using a team of scientific experts to optimise the performance of system components rapidly became an established war practice. Operations research teams were subsequently called in whenever the solution to a problem required highly technical, multidisciplinary knowledge.

As the logistical operations in the war became more challenging, operations research became an integral part of the war effort. In the context of post-

war developments, *Progressive Architecture* (1968: 113) reports as follows:

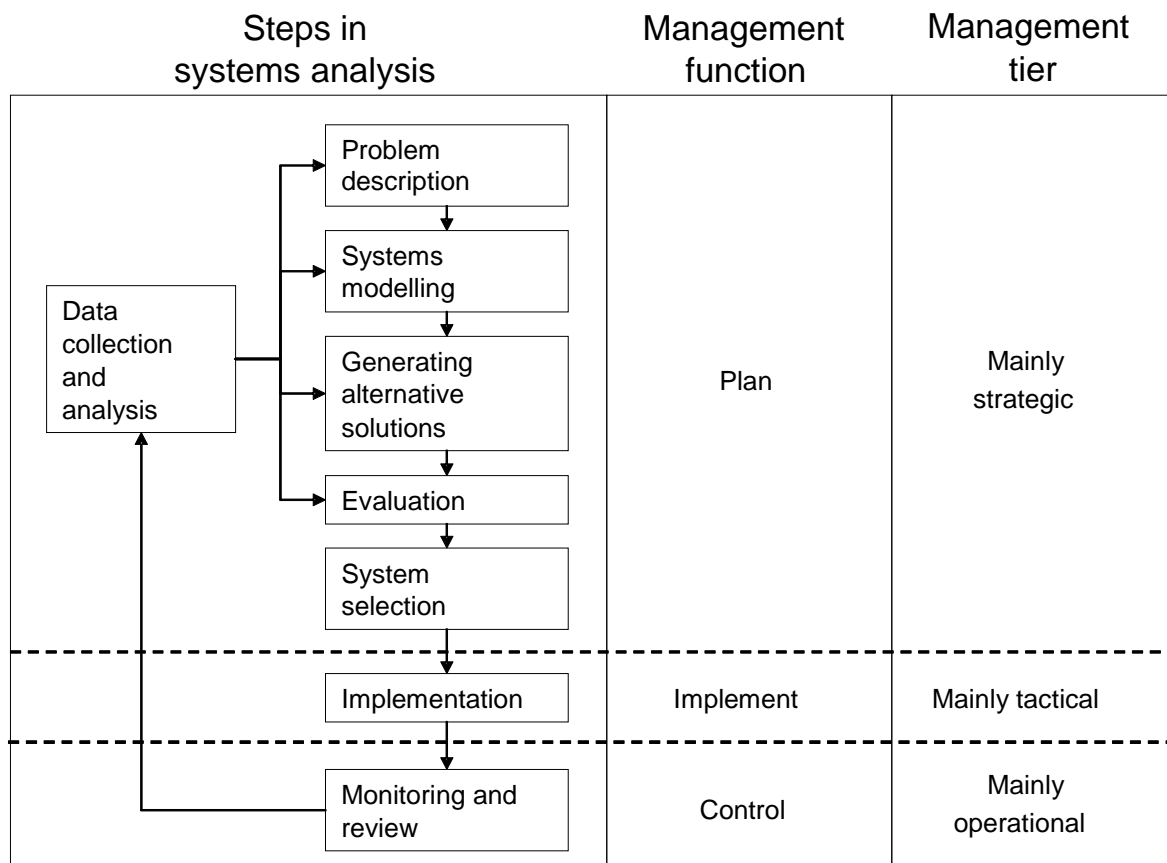
So the stage was set for the post-war development of systems analysis and operations research in many fields – civilian and space age, as well as military. The basic concept of expert teamwork, scientific method, and sequential treatment of all parameters of a problem was found to be ideally amenable to evolution through more sophisticated concepts of research and investigative methods (computers, information retrieval devices, and so on). Today, there would seem to be few areas of planning or research immune to the potential of systems analysis and problem-solving when imaginatively pursued and constructively used.

The systems approach is ideal for the solution of logistical problems where the need for goods, services and information (demand related); production and distribution capacity (supply related); and the operating environment vary with time.

The systems-analysis process comprises the following seven consecutive steps:

- 1) Define objectives and determine the levels of service that are needed to achieve the objectives (i.e. problem description).
- 2) Conceptualise the existing operating system and environment through research and simulation of the status quo (i.e. systems modelling).
- 3) Generate technically feasible alternative solutions (i.e. generate alternative solutions).
- 4) Apply optimisation and assessment techniques to determine the viability of the prospective investment options and operating procedures (i.e. evaluation).
- 5) Select the most viable investment options and operating procedures (i.e. system selection).
- 6) Organise the implementation of the chosen system (i.e. implementation).
- 7) Formulate and apply appropriate performance measures in order to judge the success of the logistics execution (i.e. monitoring and review).

If monitoring and review show that a permanent gap is developing between the performance and the objectives of a system, it means that a fundamental system problem requiring more than short-term action has been identified. Hence, the cycle of analysis will start anew. In Figure 2 the arrows (depicting the direction of the flow) show that the systems analysis process has no definite cut-off point: as soon as a fresh problem emerges, the monitoring and reviewing phase takes the whole process back to the initial stages of the analytical cycle.

Figure 2. Coherence between the systems analysis and logistics management approaches

Source: Pienaar & Vogt 2009: 9

3 OPERATIONS RESEARCH COMPETENCIES REQUIRED IN THE EXECUTION OF LOGISTICS PRACTICE

3.1 Empiric research

Research was conducted by the Department of Logistics at Stellenbosch University (the Department) to determine the scope of analytical skills that logisticians and operations researchers should possess in order to execute business logistics practice. The investigation entailed the following four steps:

First, the experience gained by the Department from teaching logistics management as an academic subject since 1992 was used to help judge which quantitative ('model using') skills are needed by logistics managers and which quantitative ('model building') skills are needed by logistics analysts. Second, the opinion of logistics managers from 66 organisations in the various economic sectors was sought to determine which quantitative competencies a logistician should ideally possess. Of these organisations, 14 were in the primary (i.e. production) sector; 18 in the secondary (manufacturing) sector; and 34 in the tertiary (i.e. service) sector. Third, a study was undertaken of the content of 12 logistics and operations research textbooks that are used internationally in order to determine which operations

research methods and techniques are discussed most within the context of logistics management (Pienaar 2005: 88; 2006: 116). Fourth, during curriculum revisions the Department had the opportunity to consider the recommendations made by teams of external evaluators who officially evaluated the Department's academic offering in 1995, 2002 and 2009. The panels of external evaluators consisted of leading South African and international operations researchers and logisticians. The results of these investigations are summarised in section 3.2 (Stellenbosch University 2011).

3.2 Research results

In addition to tertiary-level skills in mathematics, probability theory, statistics and the theory of interest, and the ability to use financial, mathematical and statistical analysis techniques required for effective logistics management, the above-mentioned investigation indicated that logistics analysts should be competent in at least eight of the functional areas of operations research. These areas of competency are (in order of importance): (1) decision making; (2) forecasting; (3) scheduling (of machines, production, vehicles, crews and projects); (4) vehicle route planning; (5) inventory control; (6) facility location;

(7) analysis using simulation; and (8) applying queuing theory.

The six most important groups of operations research techniques to achieve these competencies are: (1) network optimisation; (2) linear programming; (3) combinatorial optimisation; (4) multi-criterion decision analysis; (5) nonlinear optimisation; and (6) probabilistic modelling.

4 LOGISTICS SYSTEMS CONTROL

4.1 Background

Control includes monitoring and reviewing performance to ensure that (1) the logistics process satisfies customers effectively; (2) the organisation's resources are deployed efficiently; and (3) corrective action is taken when performance is not in line with goals and objectives (see Figure 2). A continuing challenge for logistics managers is to develop and maintain an effective set of measures to inform decision making and support the achievement of financial success. Both financial and non-financial measures should be pursued. Since financial results within organisations are generally made known deep into the following financial period, they have little value for day-to-day operational logistics management. A more immediate method of controlling logistics performance is needed to monitor daily activities. This article focuses on the employment of non-financial measures that can be used to (1) monitor and review logistics performance; and (2) that are capable of providing diagnostics for use in problem resolution and improvement processes.

Performance measures should satisfy three basic requirements:

- 1) Collectively they should measure the performance of the whole system.
- 2) They should be quantifiable.
- 3) They should be statistically reliable, and capable of being obtained within a relatively short period at reasonable cost.

Logistics measurement systems have been traditionally designed to include information on five types of performance: (1) customer service; (2) logistics quality; (3) cost; (4) asset management; and (5) personnel productivity (Bowersox et al. 2010: 384). The first two of these performance areas are mainly focused on logistics effectiveness, while the latter three are concerned primarily with logistics efficiency. Several measures can be designed and implemented to specifically manage each of the logistics activities (shown in Figure 1), such as transport, warehousing and inventory control. Research suggests that leading-edge organisations are focused on performance measurement across these five areas, which collectively serve as a representative platform on which competitive position, value-adding capabilities and supply chain integration can grow

(Fawcett & Cooper 1998: 341; Gunasekaran & Kobu 2007: 1995).

4.2 Research methodology

From the 66 logistics-oriented organisations mentioned in section 3.1, the opinion of 27 representatives involved in logistics performance measurement was solicited regarding the matter. The respondents all confirmed that, in their opinion, the five performance areas mentioned in section 4.2 as a whole can sufficiently represent organisational logistics performance in South Africa. The representatives were further asked to rank the five diagnostic measures that are most indicative of eventual financial success within each logistics performance area. Their average ranking per area appears in section 4.3.

4.3 Survey results

(1) Customer service

In order to determine whether the desired goods, services and information are consistently made available at the designated place and time, and in the required condition and quantity, feedback should be obtained directly and explicitly from the customer. In doing so, the following measures were judged to be most critical:

- i. Percentage of consignments delivered at the right (i.e. designated) place
- ii. Percentage of consignments delivered on time (i.e. at the designated time)
- iii. Percentage of consignments delivered damage free (i.e. in the required condition)
- iv. Percentage of consignments delivered complete (i.e. in the required quantity)
- v. Percentage of orders fulfilled and invoiced accurately

(2) Quality

Logistics quality is closely related to the objective of achieving optimal customer service. Whereas customer service refers to how effectively customers' desires are conformed to, logistics quality refers to how efficiently (or cost effectively) customers' desires are met. From this perspective, the following measures were indicated as being most important:

- i. Damage frequency
- ii. Frequency of credit claims by customers
- iii. Frequency of product returns by customers
- iv. Ratio of orders sorted, packed, shipped and delivered accurately
- v. Ratio of orders documented and invoiced accurately

In (i) above, *damage* excludes faulty products that erroneously leave production/manufacturing and enter distribution. The reason for this exclusion is that

production and manufacturing are not logistics activities (see Figure 1). Of the 27 respondents, 25 representatives confirmed that their organisations monitor *damage frequency*. Twenty of the respondents indicated that they monitor damage incurred per individual logistics activity, for example during storage, materials handling and transport. In order to analyse the nature and cost consequences of product *damage frequency*, all of the respondents confirmed that they also record the *number of credit claims* and the *number of product returns*. Note that measure (iv) above refers to functional (i.e. physical) logistics quality, and that measure (v) refers to administrative logistics quality.

(3) Logistics cost

Logistics cost (LC) is the direct reflection of monetary input required to accomplish specific logistics output, or availability/readiness to provide acceptable logistics service. According to the respondents, the following logistics cost measures are applied most:

- i. Comparison of actual LC versus budgeted LC
- ii. LC as a ratio of sales revenue
- iii. LC per unit delivered
- iv. Cost per logistics function (e.g. coordination of inbound traffic, transport, warehousing, inventory control)
- v. Comparison of current LC to historical cost standard (in real terms)

In general, the respondents indicated although *logistics cost* as a performance measure is not inherently diagnostic, however, it (1) alerts systems analysts to expeditiously pursue diagnostic investigation; and (2) gives guidance and often provides prognostic clues for the analysis of asset performance and personnel productivity (including untoward human behaviour).

(4) Asset management

Asset management is concerned with the utilisation of the organisation's mobile equipment (e.g. vehicles and handling equipment), durable installed and stationary assets (e.g. workshop equipment), and current assets in the form of inventory (i.e. merchandise). The following measures were indicated as being the most important:

- i. Fixed-asset output: Examples for vehicles: Ton-km per period, container-km per period, deliveries per period, fuel consumption rates, tyre wear
- ii. Fixed-asset time utilisation (FATU) ratio = Actual working time ÷ Total number of hours available (Downtime ratio = 1 – FATU)
- iii. Inventory turnover (A = Units sold in a period ÷ Average units in stock during the period

- iv. Inventory turnover (C) = Sales revenue in a period ÷ Average inventory at sales price during the period
- v. Inventory turnover (B) = Cost of goods sold in a period ÷ Average inventory at cost during the period

Respondents indicated that measure (iv) is generally applied when dealing with raw materials and semi-finished goods (which can often be stockpiled), and that measure (v) is in general applied when dealing with finished goods (which are time sensitive).

(5) Personnel productivity

Personnel productivity refers to the quantity of output divided by the amount of human resources input employed to produce the output. The following human resources-related productivity measures were indicated to be mostly considered in logistics management:

- i. Comparison of actual achievement versus target achievement
- ii. Number of units delivered per human resources cost amount
- iii. Number of units carried/delivered per warehouse/transport employee
- iv. Average order cycle time
- v. Comparison to historical standard

Note that measure (iv) is not a ratio – it represents the average time duration between the reception and fulfilment of orders

5 CONCLUSIONS

The objective of logistics management is to ensure that the desired goods, services and information are continuously made available at the destined place and designated time, in the required condition and quantity, at an acceptable cost. An integrated logistics process with cross-functional coordination achieved through the application of operations research methodology should lead to the aforementioned acceptable cost. The systems analysis approach is ideal for the solution of logistical problems where, firstly, the demand for goods, services and information, secondly, the supply of production and distribution capacity, and, thirdly, the operating environment vary with time. The aim of systems analysis is to methodically solve problems that entail the identification, study and evaluation of interdependent parts and their attributes that function in an ongoing process and that constitute an organic whole.

Operations research may be regarded as an indispensable toolkit for the logistician. The following eight tools are the most important instruments in this kit: (1) decision making; (2) forecasting; (3) scheduling; (4) route planning; (5) inventory control; (6) facility location; (7) analysis with simulation; and

(8) applying queuing theory. The six most important groups of operations research techniques to achieve these competencies are: (1) network optimisation; (2) linear programming; (3) combinatorial optimisation; (4) multi-criterion decision analysis; (5) nonlinear optimisation; and (6) probabilistic modelling.

Controlling the execution of logistics activity is achieved through applying appropriate performance measures that reliably indicate when the logistics system requires adjustment to bring its performance in line with the organisation's goals and objectives. The success in achieving the latter can adequately be attained through effectively monitoring and reviewing performance in the following areas of a business logistics system: (1) customer service; (2) logistics quality; (3) cost; (4) asset management; and (5) personnel productivity. Logistics systems analysts who are proficient in applying the above-mentioned eight operations research tools and the six identified techniques to optimise the performance of a logistics system are most likely best suited to construct and maintain the system's control process.

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