ARTICLE IN PRESS

Robotics and Autonomous Systems ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Robotics and Autonomous Systems

journal homepage: www.elsevier.com/locate/robot

Risk assessment for multiple automated guided vehicle manufacturing network

Hamed Fazlollahtabar *, Mohammad Saidi–Mehrabad

Faculty of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran

HIGHLIGHTS

- Proposing a risk based dynamic program to determine more reliable paths.
- Developing a dynamic multi stage decision making process of the multiple AGVs.
- Employing Bayesian approach to determine the loss function of AGVs moving.
- Designing a heuristic optimization process as solution approach.

ARTICLE INFO

Article history:
Received 30 December 2013
Received in revised form
10 April 2015
Accepted 20 July 2015
Available online xxxx

Keywords:
Automated guided vehicle (AGV)
Manufacturing network
Risk assessment
Loss function
Bayesian approach
Dynamic program

ABSTRACT

Automated guided vehicles (AGVs) are moving devices for material handling in a manufacturing system through a network of guide paths. The network is configured of nodes of work stations and arcs of guide paths. To obtain this more availability of the system having reliable arcs are desirable. Advanced manufacturing systems feasibility is considered via economic evaluation. Thus, this work proposes a risk based dynamic program to determine more reliable arcs for fortification purposes. With respect to the multi stage decision making process of the multiple AGVs on different arcs, we develop a dynamic program being a useful tool for multi stage decision making. To counteract the dynamism of data in different time periods, Bayesian approach is employed to determine the loss function of moving through the stages of the proposed AGV routing network. By increasing the number of nodes and AGVs the problem is considered in NP-hard class, and thus the required effort for optimization motivates to develop a heuristic solution approach.

1. Introduction

A standard formula for the quantitative definition of risk is, Risk $= P(\text{loss}) \times L(\text{loss})$, where risk is the function of the probability (P) of loss and the significance of its consequences (L) [1]. Hetland [2] and Diekmann et al. [3], on the other hand, view risk as the implication of an uncertain phenomenon. Waters [4] explains the difference: risk occurs because there is uncertainty about the future, which means that unexpected events may occur. Knight's [5] distinction between certainty, risk and uncertainty is probably the best known and most used typology of uncertainty for risk management. In his definition of risk Knight coined the terms (quantitative) "measurable" uncertainty and (non-quantitative) "un-measurable" uncertainty when there is only partial knowledge of outcomes in the form of beliefs and opinions [6].

The researchers' role in the discussions was to present the data and guide the discussion in a holistic direction. Consensus was finally reached about the risks, their categorization and impact. The risk drivers found from the manufacturing system were classified by source. We found that an adaptation of Manuj and Mentzer's [1] risk source classification with its wide perspective on manufacturing risk management provided a solid framework for our case; the classification is both qualitative and quantitative, taking into account both the direct and indirect impacts, and this facilitates in depth understanding of the risk sources without losing the holistic view. The risks were categorized as follows: Supply Risks, Security Risks, Operational Risks, Macro Risks, Policy Risks and Environmental Risks. No risk sources fitting the Demand Risks, Competitive Risks and Resource Risks classification were identified in the group discussions [7]. Having identified the risks and made their semi-quantitative assessment, the expert panel turned to the delay impact, which was modeled in the form

* Corresponding author.
E-mail addresses: hfazl@iust.ac.ir (H. Fazlollahtabar), mehrabad@iust.ac.ir (M. Saidi–Mehrabad).

http://dx.doi.org/10.1016/j.robot.2015.07.013

Please cite this article in press as: H. Fazlollahtabar, M. Saidi–Mehrabad, Risk assessment for multiple automated guided vehicle manufacturing network, Robotics and Autonomous Systems (2015), http://dx.doi.org/10.1016/j.robot.2015.07.013

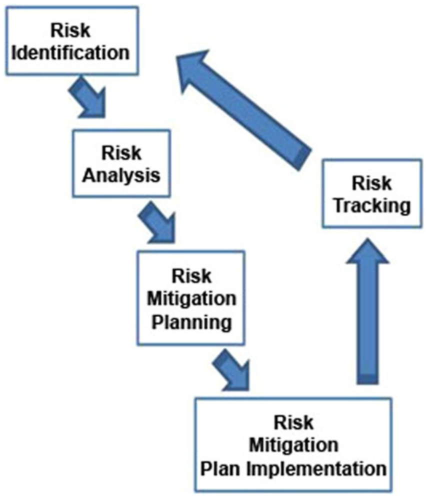

Fig. 1. Risk management process.

of triangular distributions representing the minimum, the most likely and the highest impact. Risk effects can be categorized into three different types: time-based, finance-based and quality-based. Time-based effects either delay or disrupt the material flow of the manufacturing system. In this case the disruption was identified as a breakdown in the chain such that the goods do not reach their destination by the time they are expected by the final customer. There are no clear time limitations on the delay due to the fact that it had significantly different consequences in different stages of the system. Manufacturing transportation could be delayed for times without serious consequences. The risk impact in this case varied highly depending on the goods. Risk likelihood and impact were evaluated on a scale of 0, 1, 3, 9, where 0 implies zero likelihood or no impact and 9 denotes a very high likelihood or impact. The scale is adapted from the Quality Function Deployment design method (see e.g., [8]), which is commonly used in the context of new product/ service development.

Manufacturing risk assessment is a supporting tool for the contractor and program office decision-making process. It seeks to estimate the probabilities of success or failure associated with the manufacturing alternatives available [9]. These risk assessments may reflect alternative manufacturing approaches to a given design or may be part of the evaluation of design alternatives, each of which has an associated manufacturing approach. Risk management is an overarching process that begins during the earliest stages of a program and continues throughout its entire life cycle. Risk encompasses the following steps (see Fig. 1):

- Risk identification;
- Risk analysis;
- Risk mitigation planning;
- Risk mitigation plan implementation; and
- Risk tracking.

Assessing manufacturing risks is a requirement, and it is required as early as pre-Milestone A where the Analysis of Alternatives (AoA) is required to assess the "manufacturing feasibility" of the proposed approach.

As a system progresses through its definition, design, development, testing and fielding, more information becomes available concerning the system's risk. If the risk management process is conducted continuously, then new information will lead to identifying and analyzing new risk root causes, and identifying and implementing mitigation plans for them. It will also lead to re-analyzing previously identified risk root causes, and re-evaluating and adjusting mitigation plans already in place. This continuous activity allows the PM to focus valuable program resources where they can be most effective, and shift resources as new future root causes are discovered and others are re-evaluated.

Manufacturing risk can come from many sources to include:

- Emerging critical technologies;
- Industrial base;
- Design (immature or not producible);
- Materials;
- Cost and Funding;
- Processes and process capabilities;
- Quality Management;
- Manufacturing Management;
- Facilities and equipment; and
- Personnel (skills, training and certification).

Iterative Systems Engineering process is the perfect vehicle for helping manufacturing managers to identify risk early through technical reviews and audits and to support the development of plans and mitigations to reduce those risks.

Critical success factors refer to identifying the factors that must be successfully mastered to execute a successful risk management program. Some examples of risk management critical success factors include:

- Clearly define and establish feasible, stable, and well-understood user requirements;
- Establish a close partnership with users, industry, and other key stakeholders;
- Comprehensively plan, formally document, and continuously apply the risk management process, and ensure that it is integral to all program processes;
- Use continuous, event-driven technical reviews as part of the risk management process; and
- Clearly define criteria for assessing the effectiveness of implemented risk mitigation actions.

Risk is time phased and should be tied to appropriate maturity models such as the Technology Readiness Level (TRL), Manufacturing Readiness Level (MRL) and Sustainment Readiness Model (SRM) that are considered best practices. Other chapters will discuss these models. These models provide for an assessment of a technology, manufacturing process, logistics/sustainment considerations of a component, subsystem, or weapon system. These models have been structured to:

- Define the current level of maturity;
- Identify maturity shortfalls and associated cost and risk; and
- Provide a basis for investments to mature the component, subsystem, or weapon system and thereby manage risk.

The risks were analyzed in terms of their effects on the manufacturing system. Some of the investigated organizations had severe problems informing a holistic and clear view, and clear overestimations as well as underestimations were evident in their assessment of the risk impact beyond their own functions. Expert panel discussions were held in order to verify the risk values [10]. The first of these took place during the interview process in order to discuss the preliminary findings from the interviews conducted thus far and to explore the different viewpoints. The expert panel consisted of logistics field researchers and port operations experts in the case of manufacturing system.

Here, a manufacturing network is proposed and the defects are determined in order to analyze risk and compute loss. The aim is to obtain paths with less loss and more reliability. With respect to the multi stage decision making process of the proposed network, we develop a dynamic program being a useful tool for multi stage decision making. To counteract the dynamism of digital data in different time periods, a Bayesian approach is employed to determine the loss function of moving through the stages of the proposed network.

Please cite this article in press as: H. Fazlollahtabar, M. Saidi–Mehrabad, Risk assessment for multiple automated guided vehicle manufacturing network, Robotics and Autonomous Systems (2015), http://dx.doi.org/10.1016/j.robot.2015.07.013