**RSE2107A - Identifying & Understanding Problems and Opportunities**

Introduction

* This document builds upon the previously established Engineered System Context by identifying key problems, concerns, potential opportunities, and needs of key stakeholders to understand the implementation of our autonomous robot using LIMO platform and ROS1.
* While there is no existing system failure to address, design constraints and required use of ROS1 present realistic challenges in achieving reliable autonomous navigation.
* This document therefore sets the foundation for providing a problem statement and an opportunity statement, which guide the system moving forward from product system context to service context.

Problem Identification

* Our team identified three relevant key problems that could impact the performance and success of this project. Each problem was classified based on its complexity either as a wicked problem or a regular problem. This classification helped guide our design decisions, prioritisation, and resource planning throughout the project.

| **Problem** | **Problem Type** | **Reason** |
| --- | --- | --- |
| Arena design according to given theme  (Changi Airport T3) | Wicked | Hard to design Terminal 3 theme due to constraints in scale, resources and tight timeline. (Within SEP1 scope) |
| Autonomous navigation | Wicked | The LIMO Bot offers multiple operational modes—such as Ackermann vs. differential drive, GMapping vs. RTAB-Map for SLAM, and Dijkstra’s vs. A\* for path planning—each with distinct strengths and limitations. Arena layouts can be intentionally designed to challenge or favor certain configurations. Therefore, selecting the most appropriate combination of modes requires strategic evaluation to ensure comprehensive obstacle coverage and system robustness across diverse scenarios. |
| Material selection for arena design | Regular | Must balance safety and durability with compatibility for the LiDAR and Camera while ensuring difficulty. |

Concerns Raised and Checked With

* As part of the systems approach, we identified early challenges that could affect this project. These problems were surfaced through team discussions, initial planning, and consultations with stakeholders. Each identified issue was validated where possible with stakeholders and linked to specific learning outcomes, guiding how we move the system forward.

| **Concerns** | **Validated with** | **Learning Remarks** |
| --- | --- | --- |
| Obstacles - what kind of elements are acceptable without affecting the LIMO bot? Our initial team’s ideas include moving conveyor belt and gantries | Professor Yohannes | No multistory designs. Avoid using reflective or moving props. May lead to LiDAR false reading and sudden moving changes can confuse SLAM. Obstacles cannot be permanent blockage as well. |
| Criteria and grading - What is evaluated, and what should we look out for in both arena and LIMO bot? How do we ensure our work meets the expected standards? | Professor Yohannes | Project should meet certain standards, which are:  -overall aesthetics  -successful navigation  -workmanship  -resemblance to theme  -obstacle avoidance  These guided our material choices, props placement, and obstacle design to ensure our arena not only adheres to the theme but also supports autonomous performance. |
| Crafted questions regarding concerns for systems approach. Main topic- Stakeholders Responsibilities | Professor Liew | Explained inconsistency of stakeholders responsibilities in SEBoK and should not be interpreted too literally.  We learned that real-world projects require structured stakeholder identification, where each person's role is tied to decision-making authority and sign-off responsibilities.  Thus for this project, we still listed stakeholders but recognised that they serve different functions — some provide technical support, others validate system decisions  This led us to revise our stakeholder list with clear professional roles and technical expectations. |
| Crafted questions regarding systems approach. Main topic- System Context | Professor Liew | Explained system context is not just the physical robot or arena, but the broader concept you build the system around.  This helped us realise the importance of framing our project in a real-life simulation context, and to be specific about what we are demonstrating, to whom, and why. It also shaped how we approached our competency goals and the justification for our system boundaries. |
| Crafted questions regarding systems approach. Main topic- SoI definition | Professor Liew | Explained not to force-fit SEBoK concepts without understanding their intent.  We initially tried to strictly apply the notion of authority within NSoI/WSoI boundaries, but learned that not all SEBoK elements apply directly to student projects. Our takeaway was to critically apply SEBoK, identify what fits our problem, and avoid process paralysis. |

Stakeholders & their Needs

* As part of the systems approach, we identified key stakeholders involved in this project and considered their individual needs and roles. These stakeholders either directly influence system requirements or provide support and validation during development. Understanding their needs helped to ensure our choices, testing goals, and documentation with the expected standards and outcomes of the project.

| **Stakeholder** | **Role** | **Needs** |
| --- | --- | --- |
| Prof Ang | LIMO bot Evaluator | Program LIMO bot that can navigate the entire arena autonomously |
| Prof Yohannes | Arena Design Evaluator | Approval of arena layout based on criteria and gradings |
| Prof Liew | Systems Approach Evaluator | Expects clear documentation and traceable logic |
| Mr Gary | Lab Technician | Provides lab tools, 3D printing services, material access |

Constraints

* Our project had to follow several fixed constraints set by the scope. These rules helped keep things fair across teams and made the project more controlled. They affected how we planned our arena, how the robot moved, what resources we used, and how we worked with other teams. Understanding these constraints helped us make better decisions during design and testing.
* Plot size: 1.5m x 1.33m
* Plot openings must be at the centers of the sides.
* Robot must perform localisation, path planning, mapping, navigation, obstacle avoidance
* The robot’s path must intersect and be within 5cm radius from the center of the arena.
* Robot must navigate around with other teams’ plot
* Sourcing own materials as well as determine own dimensions
* Allocated budget: $600

Problems and Opportunities

To illustrate how a structured system approach can guide the integration of existing robotic components using ROS1 for mapping, localization, and navigation across a multi-plot terminal arena. This project focuses on defining clear system boundaries, stakeholder requirements, and verification steps.

From Product system context to Service system context

* Service: “Autonomous corridor patrol and delivery” in an airport terminal environment.
* Provider: The robotics team operating the LIMO Bot fleet following the systems‐engineering process.
* Customers: Airport operations (maintenance, security, logistics) & Passengers (for wayfinding assistance, baggage escort).
* Proposition: Continuous, reliable autonomous patrols and small parcel/ticket delivery along airport corridors.

| **Aspect** | **Product System Context** | **Service System Context** |
| --- | --- | --- |
| SoI | Terminal 3 plot (1.5 m×1.33 m) + LIMO Bot with ROS1 stack | Autonomous patrol/navigation service operating across any sequence of plots using the same plot+bot modules |
| Deliverable | One‐time demonstration of end-to-end navigation | Ongoing corridor monitoring, delivery, or inspection runs delivering continuous operational value |
| Stakeholders | Professors (demo judges), Technical Staff (lab support) | Service Consumers: Professors (commissioners), Future Employers & Operators (end-users of the service) |
| Key Processes | Design → Build → Test (per plot) | Schedule → Dispatch → Execute → Log → Maintain → Iterate |
| Handover & Acceptance | Handoff to judges at demo completion | Service‐level agreements (SLAs) for run frequency, performance metrics, maintenance intervals |
| Resource Focus | Plot fixtures, ROS configurations, single SLAM map | Fleet of plot+bot modules, shared network/infrastructure, charging/workflow management |
| Operational Lifecycle | Demo-to-demo handover | Continuous operation with feedback loops for map updates, parameter tuning, and hardware maintenance |
| Scalability | Eight-plot chained demo | Extension to larger facilities or multiple simultaneous patrols using the same protocols and interfaces |
| Feedback & Improvement | One-off grading metrics (run time, collisions) | Continuous performance logging (rosbags, diagnostics) feeding iterative refinements and service reports |